ENERGY TRANSITION IN CEMENT INDUSTRY'S POWER PLANT

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Preface

In the ever-evolving landscape of industrial progress, few sectors stand as emblematic of both tradition and innovation as the cement industry. Cement, the very foundation of modern infrastructure, has long been synonymous with durability and strength. Yet, beneath the surface of its seemingly immutable presence lies a dynamic realm of change driven by a critical imperative: sustainability.

This book embarks on a journey through the heart of this transformation, focusing on a pivotal aspect often overlooked—the energy transition within cement industry power plants. As the world confronts the urgent challenges posed by climate change, industries worldwide are compelled to reevaluate their operations and embrace sustainable practices. The cement sector, renowned for its significant carbon footprint, stands at a crossroads, poised to redefine its role in the global quest for environmental stewardship.

Through meticulous research, insightful analysis, and a forward-thinking perspective, this book delves into the multifaceted dimensions of energy transition within cement industry power plants. From traditional fossil fuel reliance to the integration of renewable energy sources, from technological innovations to policy frameworks shaping the industry's trajectory, each chapter unravels a piece of the intricate puzzle driving this seismic shift.

However, this journey is not merely a chronicle of technological advancements or regulatory mandates. It is a testament to the collective resolve of industry stakeholders—from visionary leaders to frontline workers—to embrace sustainability as a guiding principle. It is a celebration of innovation, resilience, and the indomitable human spirit in the face of daunting challenges.

As the author, I am deeply passionate about the intersection of industry, innovation, and sustainability. My aspiration with this book is to illuminate the path forward for the cement industry, inspiring dialogue, driving change, and fostering a future where progress is synonymous with responsibility.

I invite you, dear reader, to embark on this transformative odyssey. Together, let us explore the untapped potential, navigate the complexities, and chart a course towards a more sustainable future—one cement kiln at a time.

Warm regards,

Dr. Anirudh Singh

Acknowledgment

I want to convey my deep gratitude to my parents for giving me the education, health, wealth, guidance, strength and resolve to finish my book. I wouldn't have been able to begin and complete my work on time without their blessing. I owe them a tremendous deal for making my dream come true. I am pleased to dedicate this thesis to them in honour of my Parent's compassionate guidance, strength, grace, and fortification.

This book's completion and submission were made possible by numerous people's advice and help. Even though my gratitude for them is insufficient, I sincerely try to convey my feelings.

First, I would like to express my deep gratitude and appreciation to my Research Supervisor, Prof.(Dr.) Mini Amit Arrawatia (Director, Directorate of Research & Development, Jyoti Vidyapeeth Women's University, Jaipur) , for her ongoing support and encouragement helping me finish my book on schedule. Her counsel and blessing assisted me in my pursuit of this research. I will always be incredibly grateful to her for this. Without your invaluable assistance, advice, feedback, and support, I could not have even attempted such a challenge.

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At last, I owe my deepest gratitude to all those who have not been recognised here but whose blessings and support have always been with me in all the ventures of my life till now.

Place: Dehradun **(Dr. Anirudh Singh)**

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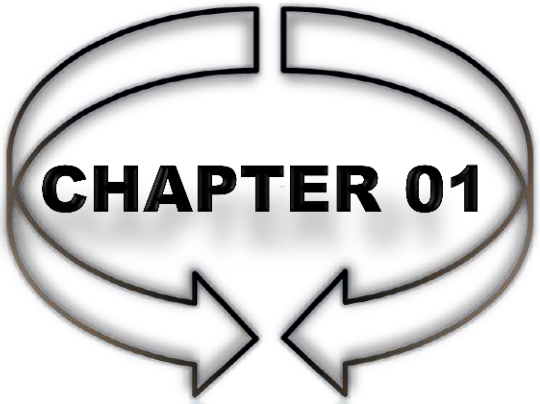

INTRODUCTION

KEY HIGHLIGHTS

- *What is Cement*
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- *Cement Manufacturing Process*
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1.1 WHAT IS CEMENT

Cement is an essential building block of development. Manufactured from limestone and other materials, it is often mixed into concrete to provide housing, roads, and pipes that supply water to communities. The world consumes over 4 billion metric tons of cement annually. The cement sector has a large economic impact due to its long and diverse supply chain and it contributes 5.4 percent of global gross domestic product (GDP) and 7.7 percent of world employment (Cembureau 2020; Fitch Solutions Group 2020; ILOSTAT 2020). At the essential level cement is a coupling substance that is plan for use in building or development material and can withstand differing ecological conditions. The four components essential for its production are iron, aluminum, silicon, and calcium (Hemidat et al., 2019). These components are scorch together in a furnace and are finely pummeled to make the powder and utilized as an element of mortar and solid; we at that point call cement. This powder solidifies once it is blend with water yet water does not break the cement once it is frame. Around 75% of cement production is utilize as a part of prepared blended cement to be use in development. The remaining 25% is utilize for clearing streets or separating oil (Portland Cement Association, 2009). The most widely recognized kind of cement is Portland. This class is separated generally into dim and white: dark is the most surely understood – a great many people allude to it when they say the word cement (Liu et al., 2020).

White is the stylish option of dark, which is utilize as a part of structures that have a tasteful segment: houses of worship, exhibition halls, and so forth. Dark Portland is produced using clinker and an extra substance generally calcium sulfate (Murray & Price, 2008). Then again, white Portland is produce using limestone, kaolin, and gypsum. A less basic sort of Portland cement is alluded to as Pozzolana Portland cement. It is utilize as a part of structures, which hope to be present to steady high stickiness or water and it, is make out of clinker, gypsum, and characteristic Pozzolana — a crude material of volcanic shakes and cinder. At long last, there is an uncommon sort of cement used in extraction of oil and withstands high weight regions called oil-well cement (Firoozi, Guney Olgun, Firoozi, & Baghini, 2017). While different sorts of cement exist, the most imperative are dark and white Portland cement as they involve the main part of cement used in developing streets, structures, and different structures.

1.2 CEMENT INDUSTRY: A GLOBAL OVERVIEW

Cement is an essential building block of development. Cement is the prime material utilized as a part of the development business. Cement utilization has an immediate connection to monetary development and change in the expectations for everyday comforts of society (Conesa, Rey, Egea, & Rey, 2011). The cement business is a capital concentrated, energy devouring, and key industry for managing infrastructure of countries. The global cement market – while constituting a small amount of world industry yield—has been developing at an expanding rate with respect to local production as of late. Endeavors to ensure the environment in developed nations – particularly Europe—have caused cement generation plants to move to nations with less stringent ecological controls. Alongside persistently rising genuine costs, this has made a concerning design on monetary productivity and natural consistence (Joseph & Otunuya, 2015). Globally, more than 1,000 cement producers operate over 2,300 integrated cement plants and over 600 grinding stations (Global Cement 2020). Five countries account for nearly three-quarters of the world's cement production: China leads with a 57-percent share, followed by India, Vietnam, the United States, and Indonesia (CW Research 2020). The majority of plants are privately owned and operated, and while the top 10 players account for about 45 percent of global capacity (Edwards 2020), the industry overall is quite fragmented. As global demand has stagnated over the last decade, historical capacity expansion has given way to regional overcapacity with a global average utilization of about 70 percent (CW Research 2020). Another challenge stems from the intensive capital investment required, and many cement companies struggle to generate returns beyond their investment.

(Source: CW Research 2020)

Figure 1: Global Cement Capacity and Production, 2019

Long-term challenge: The cement industry today accounts for 7 to 8 percent (Folliet 2020) of global carbon emissions, after improving energy efficiency and reducing greenhouse gas (GHG) emissions over the last few decades. The bulk of emissions is generate during the production of clinker, when lime, clay, and other raw materials heated in huge kilns. Rising environmental concerns among investors, governments, and society will require plants to reduce their carbon footprint. Some industry leaders are committing to carbon neutrality in cement by 2050.

1.3 CEMENT INDUSTRY: AN INDIAN PERSPECTIVE

Media transmission, oil, coal, manure, iron, steel, concrete, and so forth are the key framework divisions of India. Concrete industry is additionally assumes a huge part, in the quick development and improvement of a nation since concrete is a crucial necessity of all developments exercises. Cement is utilized as a part of lodging, dams, spans, modern development, streets and so on, so concrete is fundamental material which is utilized as a part of all kinds of developments (Corporation, 2017).

In the development of Indian assembling enterprises, libertarian contemplations of a country, building destinations have had constrained fascination as targets for industrialization. It was mostly the benefit focus that have decide their expansion and keeps on doing as such even after intendance, expect for what the general population area has been doing however not with much thought for efficiency.

These perceptions apply not just in jute and materials or iron and steel, yet in addition in cement, autos, sugar and even maybe the paper businesses, especially in the regard of the private segment leviathan. The effect of monetary components like the supply of crude materials, cost of work, cost of foundation and financial of area have all decide the development and improvement of Indian ventures however, one central point has dependably been the benefit motivating force.

In past days, different sorts of building materials utilized for development of open verifiable and religious structures sand, stone and in the exceptional case; marbles utilized for this reason. The place of common subjects was generally made of mud and thin blocks. In few cases lime and Pazzolona were utilized for getting excellent completing for the inside surface. There were great developers and mesons that have made delightful and astounding sanctuaries, structures and showering ghats thousands of years prior, still they are popular for their work and shape (John, 2020).

Nevertheless, continuously concrete and new kinds of material had created in Europe. In 1824 an English man Joseph Aspadin, licensed on fake made by calcinations of an argillaceous limestone known as Portland cement. Since concrete produced using it taken after a well-known building stone got from the ISLE of Portland close England. This was the start of Portland concrete industry, as it known today.

Cement is a powdered material with water shapes a glue that solidifies gradually. It is make by sintering a blend of different crude materials. The fundamental crude material made in the blend is calcium carbonates as limestone and other alumina, silicates as mud or shale. Amid the sintering procedure substance response happens, produces knobs, called a clinkers which comprises of calcium silicates and aluminates at the point when the clinker is pummeled with a little measure of gypsum as peruse the coming about powder is called Portland cement. Cement is essential material for a wide range of development works and it is broadly

utilize as a part of development from littlest working to biggest structures like dams, water system works, connect, modern complex and so on. To put it plainly, one might say that cement and steel are sinequa-non for that improvement of development exercises in the nation. It must enthusiasm to know how concrete is made today versus the chronicled foundation (An, Middleton, & Li, 2019).

As far back as developments ventured in the earth, individuals looked for a material that would tie stones into a strong, framed mass. The Assyrians and Babylonians utilized mud for this reason, and the Egyptians progressed to the disclosure of lime and gypsum mortar as a coupling specialist for building such structures as the Pyramids. The Greeks made further changes lastly the Romans created concrete that delivered structures of momentous solidness. The mystery of Roman accomplishment in making concrete was follow to the blending of slaked lime with Pozzolona, volcanic fiery remains from Mount Vesuvius. This procedure created cement equipped for solidifying submerged. Amid the medieval times, this craftsmanship was lost and it was not until the point that the logical soul of request restored that we rediscovered the mystery of pressure driven cement concrete that will solidify submerged.

The greater part of the building establishments in the Roman Forum built of a type of concrete set in a few areas to a profundity of 12 feet. The immense Roman showers worked around 27 B.C., the Coliseum, and the tremendous Basilica of Constantine are cases of early Roman design in which concrete mortar was utilize. Portland cement today, as in Aspdin's day, is a foreordained and precisely proportioned substance blend of calcium, silicon, iron, and aluminum. Normal concrete offered approach to Portland cement, which is an anticipated, known result of reliably high caliber(Delgado et al., 2016).

Aspadin set up a plant in Wakefield to make Portland concrete, some of which was utilize as a part of 1828 in the development of the Thames River Tunnel. Be that as it may, it was right around 20 years after the fact when J.D. White and Sons set up a prosperous processing plant in Kent that the Portland concrete industry saw its most noteworthy time of early development, in England as well as in Belgium and Germany. Portland concrete was utilize to manufacture the London sewer framework in 1859-1867. Thomas A. Edison was a pioneer in the further improvement of the rotating oven. In 1902, in his Edison Portland Cement Works in New town, N.J., he presented the principal long furnaces utilized as a part of the business—150 feet long rather than the standard 6o to 80 feet. Today, a few ovens are

in excess of 500 feet long. Parallel enhancements in squashing and crushing gear likewise affected the quick increment underway. Since crushing procedure expends the greater part of the vitality different pounding frameworks like ball process/vertical roller process/Roller presses has been the consequence of innovative advancements (Rahman, Rasul, Khan, & Sharma, 2013). Mixing happens in storehouses with air blown in from the base to circulate air through the substance. Different new plans were likewise create to expand the proficiency of blending. The cement business assumes an indispensable part in the development and advancement of a nation as it gives expected foundation to financial advancement of the nation. In our nation, a vast populace lives in towns. Streets, structures and other framework give intends to the enrollment of the monetary level of a huge country populace. Sadly, the past setup of driving cement units was not able meet the rising request of concrete in examination with their partners in alternate nations (Hemidat et al., 2019).

Cement production amid April-July 2016 saw a humble development of 4.6%, which is higher when contrasted with 1.4% development amid April-July 2015 on a YoY premise - while generation development was; bring down in April-May 2o16, the same grabbed in June 2016 upheld by pre-rainstorm request. ICRA anticipates that request development will get to 6% amid FY2017 and 7% amid FY2018. The request viewpoint for FY2o17 remains generally ideal when contrasted with 4.6% amid FY2016, driven for the most part by the get in the foundation section, fundamentally street ventures and the lodging portion, and the probability of a recuperation in the provincial request from H2 FY2017, given a superior rainstorm season. This is probably going to help cement costs in the close term. Despite the enhanced opinions in these segments, various auxiliary requirements should be deal with for venture execution to accumulate pace in the other infra sub portions. While the Government's accentuation on the framework ventures is probably going to bring about expanded open area speculations, recovery of open private association is basic for enhancing the pace of foundation improvement. The pace of recuperation in the cement business is probably going to reflect the patterns in monetary recuperation. Given the limit overhang, the limit use is probably going to stay direct at 68% in FY2017. With the pace of new limit expansion backing off and change in the supply-request situation, usage is probably going to increment to 71% in FY2018, which should bolster cement costs and productivity markers for concrete makers, particularly in FY2o18. While the vitality cost investment funds are probably going to be, weaken going ahead, given the expansion in the coal and pet coke costs amid H1

FY2017, North Indian cement makers would report better benefit numbers for H1 FY2017 versus H1 FY2016 bolstered by the noteworthy increment in cement costs. The current reconfirmation of punishment forced by the Competition Commission of India (CCI) in August 2016 (prior request was in June 2012) on most concrete organizations has not had any real negative effect on cement costs (Liu et al., 2020).

All-India cement generation revealed a direct development of 4.6% in FY2016, (to 282 million MT from 270 million MT in FY2015), with the development rate being lower than the 5.6% seen in FY2015. Amid April-July 2016, the generation at 99 million MT, announced a development of 4.6%, while unobtrusive has enhanced when contrasted with April-July 2015 at 1.4%. While the generation development amid April-May 2016 was bring down at 3.4% when contrasted with the 9%-13.5% development detailed amid Q4 FY2016, the request has gotten in June 2016 and the production expanded by 10.4% when contrasted with June 2015. The decrease in the request development amid April-May 2016 has been essentially due to the proceeded with frail country request (particularly in Maharashtra, which is confronting a dry spell) and lull in the pace of foundation execution because of the inaccessibility of water. Amid June 2016, request enhanced in most areas bolstered by the pre-rainstorm request. Amid July 2016, production has been at 23.33 million MT, a 10.5% decrease on MoM premise because of the beginning of rainstorm in most districts.

With an expected limit expansion of 16 MTPA amid FY2017 and an expected request development of 6%, the incremental request would simply surpass the incremental supply, bringing about a minimal increment in limit use to ~68% from 66% in FY2016. Concrete production development amid FY2017 is probably going to be drive by the get in the foundation section, generally street ventures and the lodging section. Further, in the southern markets, the request is probably going to recuperate amid H2 FY2017, upheld by the development of another capital for Andhra Pradesh and with the emphasis on water system and water lattice plots by the Telangana Government. Despite the enhanced conclusions in the street division and the lodging portion, various auxiliary imperatives should be deal with for venture execution to accumulate pace in the other infra sub-fragments. Further, the new undertaking declarations from the private area keep on remaining feeble. The slowed down undertakings stay sizeable with numerous ventures postponed because of ominous economic situations, subsidizing limitations, nonappearance of crude material linkages and so on. While the Government's accentuation on the

foundation ventures is probably going to bring about expanded open area speculations, restoration of people in general private association is basic for enhancing the pace of foundation advancement (Delgado et al., 2016).

The lodging division is the greatest request driver of concrete, representing around 67 for each penny of the aggregate utilization in India. The other real purchasers of cement incorporate framework at 13 %, business development at 11 for each penny and modern development at 9 %.

India's aggregate concrete production limit is almost 425 million tons, as of September 2017. The development of concrete industry is required to be 6-7 for each penny in 2017 due to the administration's emphasis on infrastructural advancement. The business is as of now delivering 280 MT for gatherings its residential request and 5 MT for sends out prerequisite. The nation's per capita utilization remains at around 225 kg.

The Indian concrete industry is overwhelm by a couple of organizations. The best 20 concrete organizations represent just about 70 % of the aggregate cement generation of the nation. An aggregate of 210 substantial concrete plants represent a total introduced limit of more than 350 million tons, with 350 little plants representing the rest. Of these 210 expansive, cement plants, 77 situated in the conditions of Andhra Pradesh, Rajasthan and Tamil Nadu.

India is the second biggest maker of cement on the planet. No big surprise, India's concrete industry is an essential piece of its economy, giving work to in excess of a million people, straightforwardly or in a roundabout way. As far back as it was deregulated in 1982, the Indian concrete industry has pulled in immense ventures, both from Indian and in addition outside financial specialists (Conesa et al., 2011).

India has a ton of potential for improvement in the foundation and development segment and the concrete segment is required to a great extent advantage from it. A portion of the current significant activities, for example, advancement of 98 brilliant urban communities are required to give a noteworthy lift to the segment.

Expecting such advancements in the nation and helped by reasonable government outside arrangements, a few remote players, for example, Lafarge-Holcim, Heidelberg Cement, and Vicat have put resources into the nation in the current past. A noteworthy factor which helps the development of this area is the

prepared accessibility of the crude materials for making cement, for example, limestone and coal (Defence, 2014).

1.3.1 Historical development

1. Era of Dominant Imports – 1914 – 1924

Amid this time of 10 years, the aggregate bond utilization was around 2 million tons: of which almost 50 for each penny comprised of imports. Starting with a creation of 1000 tons in the year 1914, the indigenous generation touched about a quarter million tons in the principal decade. In 1924 against the limit of a large portion of a million ton just 0.26 million ton was delivered.

The low limit usage and industrious issue of advertising influenced the money related practicality of the concrete plants all things considered. In addition, there was far reaching bias against the utilization of indigenous concrete. Serious rivalry among makers brought about persistent chopping down of costs. A portion of the organizations went into liquidation. The bond business was battling for it is extremely presence.

2. Era of Struggle and Survival – 1924 – 1941

Amid these 18 years, there was a slow increment in indigenous generation and abatement in concrete imports. Nevertheless, extreme rivalry among makers practically debilitated the bond business. Indigenous generation went up from 3.661akh tons in 1925 to 18.30 lakh tons in 1941. Imports dwindled from 69.000 tons in 1925 to 21,000 tons in the pre-war year 1938 and were just a couple of thousand tons in 1941. Imports added to under 7 for every penny of aggregate concrete utilization amid 1924-1942.

In 1936, war mists started assembling over Europe and subsidence had set in. Businesses in India were under impressive strain. The very survival of Indian concrete industry was in doubt. However, the Cement Marketing Co. also, Concrete Association of India had assumed their part for the advancement of bond industry it was still far beneath the desires of the bond business. Issues of advertising valuing still kept on plaguing the business. One industrialist F. C. Dinshaw - a man of incredible vision and foreknowledge - saw impressive potential for an assembled concrete industry. It was at this point F.C. Dinshaw united the bond organizations having a place with his own particular gathering, Tata's, Khataus and Killick Nixon under one pennant of Associated Cement Companies Ltd. (ACC).

3. Era of Price Controls – Pre-plan – 1942 – 1951

Amid 1942-1946, bond creation went under the domain of Defense of India Rules for generation, cost and appropriation control. Significant bit of concrete delivered at that point was reserve for Defense purposes and just around 10 for each penny was discharge for private utilization.

Amid this period, generation was venture up from 1.8 million tons in 1942 to 3.2 million tons in 1951. Imports essentially dwindled to under 2.5 for every penny of the aggregate utilization. In the following ten years up to 1956, Government of India practiced casual control by settling costs every now and then.

4. Era of Planning and Controls – 1951 – 1982

The Five Year Plans propelled from 1951-52: bond was bring under the domain of Cement Control Order of 1956 for both cost and dispersion. The control on carnet proceeded until 1982 when halfway decontrol approach was reported (concrete was decontrolled for a short period amid the two years 1966 and 1967). Interim there was "Development" in bond limit however not at the essential pace; this brought about ceaseless "Lack" until 1986.

5. Era of Partial Decontrol – 1982 – 1988

In 1977, Government reported 0.12 for every penny, post assessment form on total assets to support bond limit: this was trail by Partial Decontrol in 1982. Subsequently there was Quantum Jump in limit and generation amid 1982-88.

1.3.2 Growth drivers for cement in India

Private land segment contributed towards 63% of the aggregate household bond request in the nation amid FY06-10. As indicated by the report of the Technical Group on estimation of lodging deficiency constituted about detailing of the Eleventh Five-Year Plan, lodging lack is evaluate to be around 247.1 lakh units. Amid the Eleventh Plan period, add up to lodging necessity, including the build-up, is assess at 265.3 lakh units.

Amid the financial logjam, interest for business land dropped forcefully prompting sharp adjustment in rent rentals since the second 50% of 2008. Rent rentals have amended in the scope of 25-50 for every penny amid the principal half of 2008. With request abating generously, the greater part of the urban communities are looked with a humungous oversupply of office space. Quelled request and

rentals has affected the execution unfavorably notwithstanding cancelation of numerous undertakings. The sorted out retail land industry in India has seen a log jam in the previous year in the wake of expanding at a CAGR of 28 for every penny in 2005-08. The business is relied upon to increment at a CAGR of 14 for each penny for the time being and 19 for each penny throughout the following 5 years (Wojtacha-Rychter, Kucharski, & Smolinski, 2021).

Going ahead, between 2009-10 and 2013-14, inn industry (some portion of business land industry) request is expect to exceed supply development. Request is rely upon to increment at a CAGR of 15 for every penny while room accessibility is required to record a CAGR of nine for each penny crosswise over premium portion.

Interest in foundation is anticipate developing to Rs. 2056150 crores in the Eleventh Five Year Plan (2007-2012) from a foreseen speculation of Rs. 871445 crores in the Tenth Five Year Plan (2002-2007)12. This speaks to an exacerbated yearly development rate of 18.71%. As on January 2011, 373 SEZs had been advice and the Board of Approvals had conceded formal endorsements to 581 SEZs and on a basic level endorsement to 15413. The mechanical part contributed towards 4% of the aggregate local interest for bond in the nation.

1.4 CEMENT MANUFACTURING PROCESS

The essential science of the cement assembling process starts with the disintegration of calcium carbonate ($CaCO_3$) at around 900 °C to leave calcium oxide (CaO, lime) and free vaporous carbon dioxide (CO_2); this procedure known as calcination. This is trail by the clinkering procedure in which the calcium oxide responds at high temperature (normally 1400-1500 °C) with silica, alumina, and ferrous oxide to shape the silicates, aluminates, and ferrites of calcium, which involve the clinker. The clinker is then ground or processed together with gypsum and different added substances to create cement.

There are four principle process courses for the produce of cement; the dry, semi-dry, semi-wet and wet procedures:

- In the dry procedure, the raw materials are ground and dried to raw feast as a stream capable powder. The dry crude supper bolstered to the preheater or pre-calciner furnace or, even more infrequently, to a long dry oven.

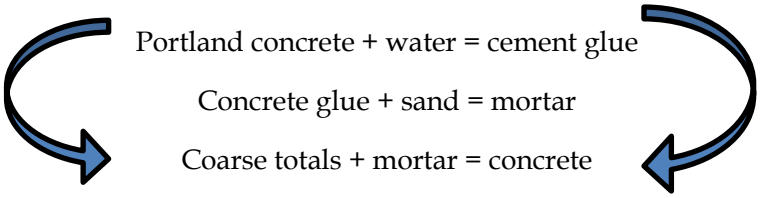
- In the semi-dry process, dry crude dinner is pelletize with water and bolstered into a mesh preheater before the furnace or to a long oven furnished with crosses.
- In the semi-wet process, the slurry first dewatered in channel presses. The channel cake expelled into pellets and nourished either to a mesh preheater or specifically to a channel cake drier for crude feast generation.
- In the wet procedure, the crude materials (frequently with high dampness content) are ground in water to shape a pump able slurry. The slurry nourished either straightforwardly into the furnace or first to a slurry drier.

Two principle techniques for cement fabricating were conspicuous, the dry procedure and the wet procedure. Dry process now has nearly supplanted the wet procedure since wet process expends high warm vitality for drying the dampness. At the point when shake is the central crude material, the initial step in the wake of quarrying in the two procedures is the essential smashing. Heaps of shake are encouraged through crushers equipped for taking care of pieces as huge as an oil drum. The principal pounding decreases the stone to a greatest size of around 6 inches. The stone at that point goes to auxiliary crushers or sledge plants for diminishment to around 3 inches or littler. It is then ground in ball factory to fine powder with different fixings like earth/press mineral/bauxite to make a blend of qualities for silica/alumina/lime and so forth in the blend. On the off chance that the procedure is wet, the pounding goes ahead in with water so slurry came about in the wake of granulating. This slurry is additionally blend in blenders and pumped to the furnace. For a dry procedure oven, the ground powder sent to mixing storehouses for uniform blending of parts included amid the granulating stage. This mixed material is encouraged to the preheated/claimer. The preheated is a gathering of twisters set more than each other wherein material descends and hot gases goes up warming the material and guaranteeing it all the while. Calcinations mean freeing carbon dioxide and changing over calcium carbonate to calcium oxide. Claimer is only a channel added to give more response time to material for calcinations. This incompletely asserted material at that point goes to the oven, which is unmanageable lined turning tube having burner fitted in the opposite end. This burner fires coal/oil/petroleum gas to make a temperature of 1600°C. At the release closes. As the material in the oven moves down towards the release end, different responses occur among the segments bringing about a mass known as clinker. This clinker is then cool in coolers. The coolers are either planetary write or mesh compose. Mesh

coolers of present day times are much productive bringing about better warmth recovery and permits reusing this warmth in the furnace. The cooled clinker at that point either goes to capacity storehouse or clinker yard. From the clinker yard, it is take for crushing. In the event that ordinary Portland cement made just gypsum, (4-6%) is included before crushing. If there should be an occurrence of Portland Pozzolona, cement added substances like fly cinder/block and so on are included. Pounding again is same like for crude material crushing with ball process or with most recent advancements like vertical plant/Roller press and so forth. The cement powder at that point taken to pressing plant or released from storehouse to a mass loader specifically.

1.4.1 Cement to concrete

The mix of cement, water, sand, and coarse totals (particles of rock or surged stone) regularly happens during the time spent solid blending is maybe best depicted as far as a straightforward three-section framework:



The concrete glue segment works in the principal case to coat and "grease up" the individual grains of sand, subsequently conferring "workability" to the mortar stage. Thus, the mortar serves to grease up the coarse total particles thus offer workability to the crisp cement. The amounts of cement glue and mortar important to accomplish sufficient levels of workability will rely upon the measures of sand and coarse 12 total present in the solid, on the related "evaluating" of constituent particle sizes, and on the real level of workability required for the activity. On the off chance that there is inadequate mortar or concrete glue, the blend will have a tendency to be "brutal" and unworkable.

On the other hand, an excessive amount of mortar or concrete glue will advance the probability of "isolation" impacts whereby the coarser total parts tend to isolate out from the rest of the blend. As opposed to prevalent thinking, concrete does not set and solidify through a physical drying-out process. Setting and solidifying is expected rather to a progression of synthetic responses between the Portland cement and water introduce in the blend; because of this alleged hydration process the first concrete glue stage is changed into a kind of "mineral paste" which

acts to tie the sand and coarse total parts together. Most regular totals are significantly more grounded than the kind of cement glues found in ordinary cements; i.e. the "mineral paste" tends to work as the weakest connection. As needs be, the quality of a solidified cement is regularly controlled by the quality of its cement glue stage. Thusly, for any given amount of cement, the related glue quality is administer as a matter of first importance by the water substance of the first blend; in this manner, the lower is the aggregate sum of blend water utilized, the more prominent is a definitive quality capability of mortar (and the other way around). On the other hand, if the aggregate blend water held consistent, the higher (or lower) is the level of cement utilization, the higher (or lower) turns into the potential quality limit of the concrete glue stage. The genuine amount of concrete glue has no genuine impact here; rather, it is the measure of cement when contrasted with the measure of water, which is the primary factor.

Solid totals ought to be generally spotless. (The crushing of "filthy" sand will for the most part deliver a perceptible stain on the palm). Filthy or dusty totals have a tendency to require much even more blending water; unless correspondingly more elevated amounts of cement use coordinate this extra "water request," quality misfortunes are likely. The nearness of tidies, sediments, or muds can likewise hinder the level of cement between individual coarse total particles and the encompassing mortar, again to a definitive disadvantage of quality; in specific conditions the antagonistic impacts of utilizing grimy totals any even reach out to impedance with the ordinary procedures of concrete hydration. It is frequently assume that totals serve to "upgrade" the quality of cement. While this once in a while applies practically speaking, nor is it the case that the total parts just capacity in the part of modest fillers. on the off chance that or when a solid dries out, the related cement glue stage will therapist to some degree; the more noteworthy is the first water substance of the concrete glue, the higher is its shrinkage potential. Ordinary totals, then again, indicate almost no shrinkage on drying. As needs be, the more prominent are the measures of sand and coarse total materials introduce in a solid blend, the lesser will be the net impact of glue shrinkage.

1.4.2 Types of cement

- Ordinary Portland cement (O.P.C)
- Portland Pazzolona Cement (P.P.C)
- Special cement

Ordinary Portland cement

This sort of cement gives enough far-reaching quality in the wake of absorbing water for 3 days, 7days and 28 days. This is appropriate for a wide range of present-day structural building developments.

The ordinary Portland cement is prominently know as dark cement, which is delivered by pounding clinker with five for each penny gypsum. It is utilize as a part of all broad cement development, mass and fortified cement. It represents around 70.60 % of the total.

Indian Standard has classified OPC in three grades based on the strength of cement. These grades are:

- Grade - 33-IS-269-1989
- Grade - 43-IS-6112-1989
- Grade - 53-IS-12269-1987

These kinds of cement are suited for every single present day sort of developments including all sorts of brickwork and solid works, for example, pre-thrown and pre-focused on concrete. They are likewise appropriate for a wide range of repair works in stonework and cementing. The higher the review of cement utilized, the more prominent would be the economy, toughness and specialized focal points. In addition, development time is additionally decrease.

Portland Pazzolona Cement

It is grayish in shading and made by crushing of limestone and earth. Consuming of limestone and earth at high temperature and cooling the resultant item is called clinker, crushing the clinker with of gypsum in ball factory to a finally ground powder. This known as Portland concrete. This concrete is deliver by adding 10 to 25 % pozzolanic materials to the open clinker at that point crushing together. It is efficiently fabricated because it utilizes fly slag/consumed earth/coal squander as the primary fixing. PPC has a lower warmth of hydration, which is of preferred standpoint in averting breaks where substantial volumes being thrown. PPC represents 18.3 % of the generation.

Special Cement

There are six types of special cement:

1. **Hydrophobic cement:** It is acquire by including water replant firm framing substance, for example, satiric corrosive and oleic acid by granulating Portland concrete clinker. This sort of concrete is lessens wetting capacity of cement grains. Henceforth it bestows more opportunity for blending, transporting, compacting and completing and so forth.
2. **Low Heat Cement:** This kind of cement is utilize for bigger mass solid works in dams, Piers and so forth. It is important to have a much lower warmth of hydration, with the goal that odds of creating development breaks are limited. This should be possible either by including a few pozzolanic material and granulated impact heater slag to the concrete while crushing by changing the compound synthesis of the cement.
3. **Rapid Hardwearing Cement:** This kind of cement is utilize for bigger mass solid works in dams, Piers and so on. It is important to have a much lower warmth of hydration, with the goal that odds of creating development splits are limited. This should be possible either by including a few pozzolanic material and granulated impact heater slag to the cement while pounding by changing the compound structure of the concrete.
4. **Quick Setting Cement:** The percentage of gypsum included decreased, which quicken the setting activity. The setting activity of this concrete is quick. This sort of cement is utilize for the submerged developments.
5. **Sulphate resistance Cement:** This concrete is inclined is obligated for crumbling under sulfate situations. Along these lines a Portland concrete, which under 5% of C3A is impervious to sulphatic activity. This concrete known as sulfate safe cement. This concrete utilized for ocean shore structure water way liming, courses and so on.
6. **White Cement:** Portland concrete is grayish in shading. The shading is because of complex shaped with press oxide exhibit in the cement. The extent of Iron oxide in the cement is diminish to under 0.4% the shade of the concrete winds up white. Press oxide show in cement crude blend helps in enhancing the consuming states of cement clinker. White cement is largely utilize for brightening works just in perspective of its high cost.

1.4.3 Characteristics of cement

1. **Setting time:** The time interim for which the concrete items stay plastic condition known as the setting time. The setting of concrete can be comprehend through beginning setting and last setting time.

2. **Strength:** Quality of concrete is not estimate on perfect cement glue because of concrete is convey out with standard sand concrete mortar. It is essential normal for concrete. Quality is estimate following 3 days, 7 days and 28 days for OPC is Kg/cm or Map.

3. **Soundless:** It is an obvious difference in the volume and there by relaxing or notwithstanding pulverizing of the solidified cement structure. It requires a long investment to finish the response procedure. Unsoundness in concrete is because of the nearness of overabundance lime, which can be taste by Le Chatelier soundless test. On the off chance, that the magnesia content is over 3% the cement is to be cheek for soundness via autoclave test. Overabundance Gypsum (more than 2 to 3%) can likewise cause the extension and diversion of set concrete structure. It can be because of overabundance of lime, magnesia, abundance sulfate. According to: 269, 8112, 12269, and 1489. Auto clave Expansion: Max. 0.8% with the expectation of complimentary magnesia content. Le Chatelier Expansion: Max 10 mm with the expectation of complimentary lime content.

4. **Fineness:** It is measure by how fine the cement grounded. It shows the surface area. It is important for setting and strength. Higher the fineness, strength and early setting achieved. As per is 269 (OPC 33G), 8112 (OPC 43G), 12269 (OPC 53G) Specified: finesse > 225 M2/Kg As per is 1489 (PPC) Specified: Fineness > 300 M2/Kg.

5. **Standard Consistency:** It is measure by water required for 33 mm to 35 mm infiltration of needle or plunger in abandon device. It is require for all further trial of cement i.e. setting test, soundness test, and quality test.

1.4.4 Grade of cement

Review of concrete shows the base compressive quality at 28 years old days in (Map) according to the determinations of Bureau of Indian benchmarks i.e. for 43 G. OPC cement must give min. 43 Map compressive quality there are for the most part three review cement accessible in showcase i.e. 33 G, 43 G, 53 G. It watched and

all around suggested that the 43 G, OPC is especially reasonable and adequate for general development work like block work, putting, and RCC structures. 53 levels is prescribed to use for pre thrown and restressed common works like flame broils, funnels, shafts, railroad shoes, empty or strong blocks, solid street. High early quality accomplished because of higher c3s content. It confers high warmth of hydration so watchful and broad curing after; development is required. It is actuality that higher level cement more C3s than C2s. C3s delivers more warmth and Ca(OH)2 (Calcium Hydroxide) which isn't alluring item in mass cement since it is solvent in water and get drained out of solid making concrete permeable and in this way diminishes the sturdiness.

Reaction of C3S with water is as under:

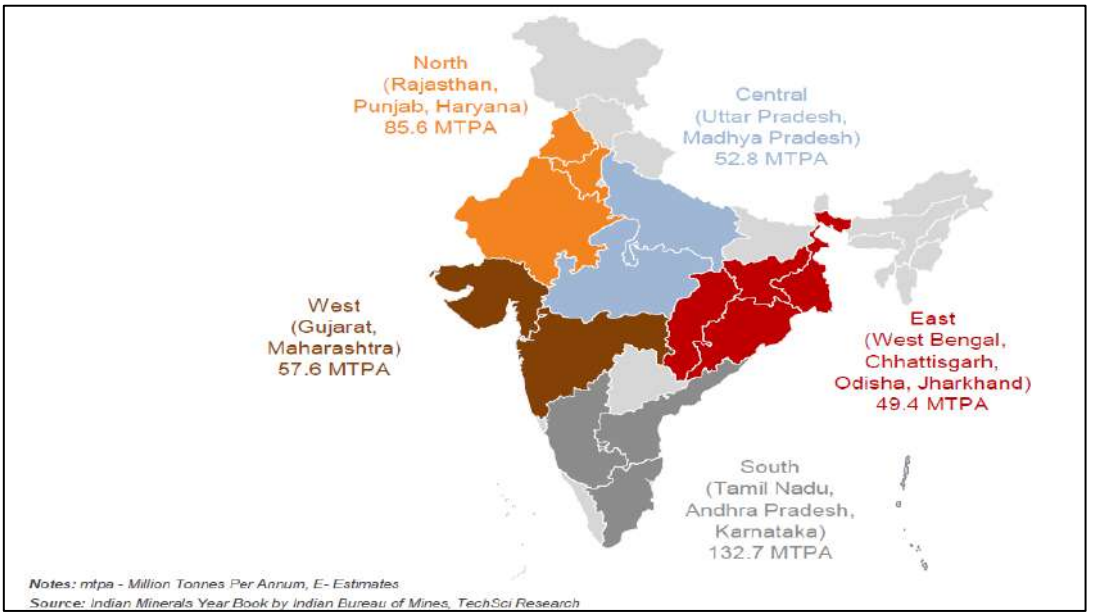
2 (3 Cao, SiO_2) + 6 H_2O -> 3CaO.2SiO_2.3H_2O+3Ca (OH) 2 2C_3S+ 6H -> $C_3S_2H_3$ + 3Ca (OH) (10O) + (24) -> (75) + (49).

1.5 INDIAN CEMENT INDUSTRY ANALYSIS

India is the second largest producer of cement in the world. It accounts for more than 7% of the global installed capacity. India has a lot of potential for development in the infrastructure and construction sector and the cement sector expected to get benefit from it. Some of the recent initiatives, such as development of 98 smart cities, it is expect to provide a major boost to the sector.

Aided by suitable Government foreign policies, several foreign players such as Lafarge-Holcim, Heidelberg Cement, and Vicat have invested in the country in the recent past. A significant factor, which aids the growth of this sector, is the ready availability of raw materials for making cement, such as limestone and coal.

India’s overall cement production accounted for 294.4 million tonnes in FY21 and 329 million tonnes in FY20.



(Source: Indian Minerals Year Book by Indian Bureau of Mines, TechSci Research)

Figure 2: Cement Map - India

1.5.1 Market size

Cement production reached 329 million tonnes (MT) in FY20 and is projected to reach 381 MT by FY22. However, the consumption stand at 327 MT in FY20 and will reach 379 MT by FY22. The cement production capacity estimated to touch 550 MT by 2020. As India has a high quantity and quality of limestone deposits throughout the country, the cement industry promises huge potential for growth.

In FY22, the cement production in India is expect to increase by ~4-7% YoY, driven by the government's strong focus on infrastructure development.

As per Crisil Ratings, the Indian cement industry is likely to add ~80 million tonnes (MT) capacity by FY24, the highest since the last 10 years, driven by increasing spending on housing and infrastructure activities.

According to CLSA (institutional brokerage and investment group), the Indian cement sector is witnessing improved demand. Key players reported by the company are ACC, Dalmia and Ultratech Cement. In the second quarter of FY21, Indian cement companies reported a sharp rebound in earnings and demand for the industry increased, driven by rural recovery. With the rural markets normalising, the

demand outlook remained strong. For FY21, CLSA expects a 14% YoY increase in EBITDA in the cement market for its coverage stocks.

1.5.2 Investments

According to the data released by Department for Promotion of Industry and Internal Trade (DPIIT), cement and gypsum products attracted Foreign Direct Investment (FDI) worth US$ 5.87 billion between April 2000 and March 2021.

In 2021, working remotely is being adopted at a fast pace and demand for affordable houses with ticket size below INR. 40-50 lakh is expected to rise in Tier 2 and 3 cities, leading to an increase in demand of cement.

Some of the major investments in Indian cement industry are as follows:

- In August 2021, Ambuja Cement announced to invest Rs. 310 crore (US$ 41.82 million) to expand its manufacturing capacity in Ropar Unit, Punjab and cater to the rising demand from manufacturing sector for housing construction and public infrastructure development. The expansion activities are expecting to be complete by June 2023.
- In July 2021, Ramco Cements launched Ramco Super Plaster, a plastering solution for brickwork and plastering applications.
- In July 2021, Vedanta announced that its aluminium unit invited bids for alliances from cement manufacturing companies such as JK Cement, ACC and UltraTech Cement to utilise fly ash, a by-product, to produce low-carbon cement.
- In July 2021, Ramco Cements announced its plan to invest US$ 64 million in capacity expansion and modernisation activities of its plant unit in Tamil Nadu.
- In July 2021, Dalmia Bharat Ltd. announced its plan to raise the company's production capacity to 110-130 million tonnes per annum by 2031.
- In July 2021, JSW Cement signed an agreement with Synergy Metals Investments Holding Ltd. and Apollo Global Management Inc. to raise investment funds worth Rs. 1,500 crore (US$ 202.35 million) and expand its production capacity to 25 million tonnes from 14 million tonnes.

- In July 2021, Shree Cement announced to invest INR. 600 crore (US$ 80.94 million) in cement grinding unit in West Bengal and start project activities by August 2021. The project is expected to provide 150 direct jobs and >1,000 indirect jobs.
- In June 2021, Ambuja Cements and ACC announced to invest in Industry 4.0 under its 'Plants of Tomorrow' programme, which aims to boost cement manufacturing through enhanced plant optimisation, improved plant availability and a safer operational environment.
- In June 2021, Ramco Cements Limited commissioned the Line III of its Jayanthipuram Plant, with a clinker manufacturing capacity of 1.50 million tonnes per annum.
- In June 2021, JSW Cement entered construction chemical business with the introduction of an exclusive green product range.
- In March 2021, UltraTech Cement acquired 3B Binani Glass fibre Sarl Luxembourg, a subsidiary of Binani Industries
- In February 2021, IBM collaborated with Shree Cement to run their database and core business applications using AIX and Red Hat on IBM POWER9-based IBM Power Systems. The implementation will allow Shree Cement to seamlessly enhance its productivity and enable supply chain efficiencies across its manufacturing plants.
- In January 2021, the company announced its plan to invest US$ 137 million to increase production capacity of its integrated cement plant in Guwahati, Assam, by 2 MTPA. The expansion plan is likely to complete by mid-2023.
- In April 2021, ACC announced the expansion plan of its grinding unit in Tikaria with a 1.6 MTPA cement capacity.
- In January 2021, ACC commissioned its new grinding unit at Sindri, in Dhanbad District of Jharkhand, adding an additional capacity of 1.4 million tonnes per annum to the existing 3 MTPA unit.

1.5.3 Government initiatives

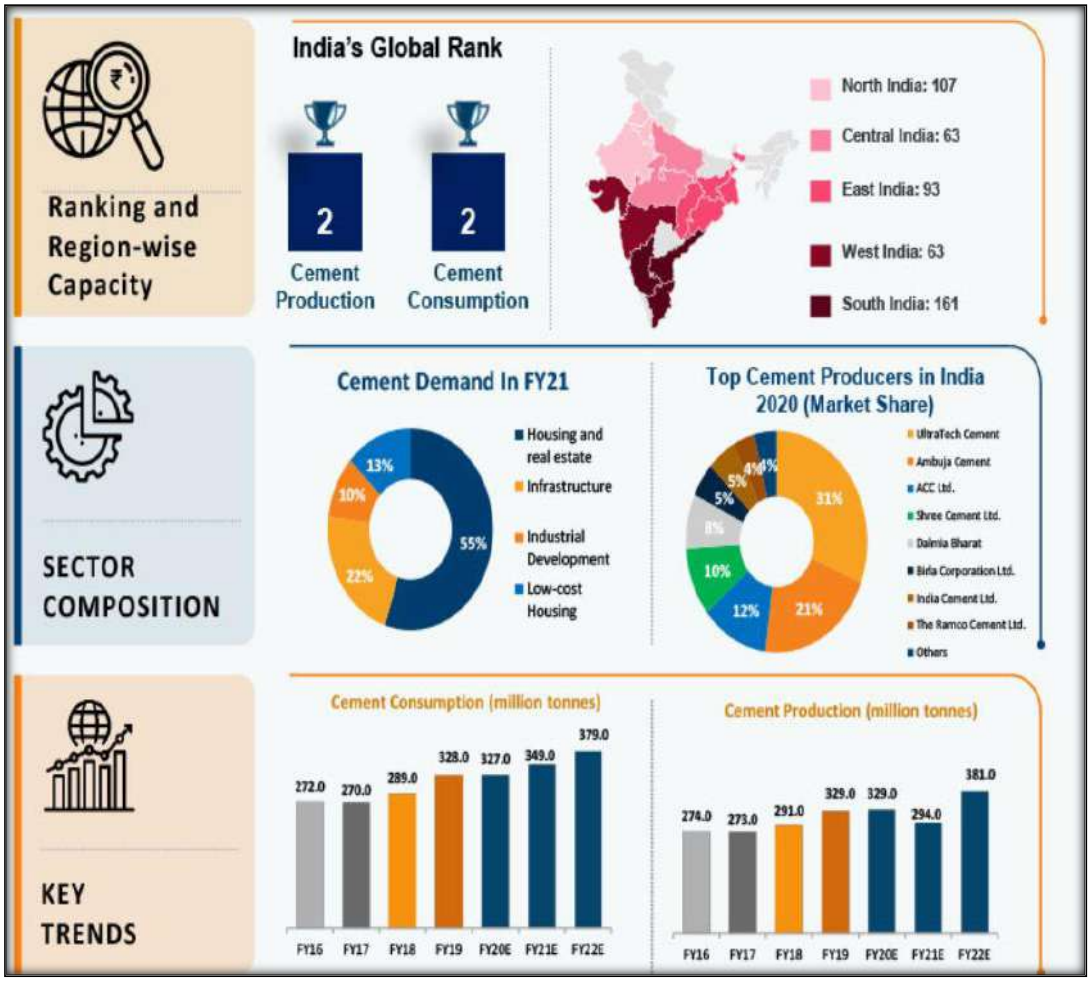
In order to help private sector companies, thrive in the industry, the Government has been approving their investment schemes. Some of the initiatives taken by the Government off late are as below:

- In July 2021, the government established a council of 25 members (comprising UltraTech Cement MD Mr. K C Jhanwar, Dalmia Bharat Group CMD Mr. Puneet Dalmia) for the cement industry to reduce waste, achieve maximum production, enhance quality, reduce costs and encourage standardisation of products.
- In Union Budget 2021-22, the Government of India extended benefits, under Section 80-IBA of the Income Tax Act, until March 31, 2021, to promote affordable rental housing in India.
- As per the Union Budget 2021-22, the government approved an outlay of INR. 1,18,101 crore (US$ 16.22 billion) for the Ministry of Road Transport and Highways, and this step is likely to boost the demand for cement.
- As per the Union Budget 2021-22, National Infrastructure Pipeline (NIP) expanded to 7,400 projects from 6,835 projects.
- The Union Budget allocated Rs. 13,750 crore (US$ 1.88 billion) and Rs. 12,294 crore (US$ 1.68 billion) for Urban Rejuvenation Mission: AMRUT and Smart Cities Mission and Swachh Bharat Mission, respectively and Rs. 27,500 crore (US$ 3.77 billion) has been allotted under Pradhan Mantri Awas Yojana.

1.5.4 Road ahead

The eastern states of India are likely to be the newer and untapped markets for cement companies and could contribute to their bottom line in future. In the next 10 years, India could become the main exporter of clinker and gray cement to the Middle East, Africa, and other developing nations of the world. Cement plants near the ports, for instance the plants in Gujarat and Visakhapatnam, will have an added advantage for export and will logistically be well armed to face stiff competition from cement plants in the interior of the country. India’s cement production capacity is expect to reach 550 MT by 2025. Due to the increasing demand in various sectors such as housing, commercial construction and industrial construction, cement industry is expected to reach 550-600 million tonnes per annum (MTPA) by the year

2025. A number of foreign players are also expecting to enter the cement sector owing to the profit margins and steady demand (figure 3).



(Source: Indian Minerals Year Book by Indian Bureau of Mines, TechSci Research)

Figure 3: Growth of Cement Industry in India

1.6 EMISSIONS IN THE CEMENT INDUSTRY

Over half of the aggregate Co2 from cement production comes about because of the compound response that changeover limestone into clinker, the dynamic fixing in concrete. This compound response accounts for roughly 540 kg Co2 for every ton of clinker. The following 40% of emanations result from consuming fuel, and the last

10% are from transportation and electricity. Clinker is made by warming limestone, mud, bauxite and iron at temperatures of more than 1,400˚C of every along revolving furnace. It is then underground with gypsum and different cementitious materials to create concrete. Delivering the high temperatures important to drive the response requires a lot of vitality. Furnace fuel represents approximately 86% of all vitality required in the production process. Carbon-escalated coal and pet-coke are the most normally utilized fills, and their burning records for the dominant part of vitality related outflows. As indicated by Getting the Numbers Right, a worldwide venture sorted out by the Cement Supportability Initiative, delivering one ton of clinker produces a normal of 825 kg of Co2, barring outflows from power age. The best-performing plants have outflows in the scope of 65o kg Co2 for each ton of clinker. In Canada, the normal is 855 kg Co2/t. It ought to be notice that the information incorporates all organizations who are individuals from the activity, yet enrollment is willful. The worldwide normal esteem may in this manner belittle the genuine worldwide normal. Ontario's six plants create around six million tons of cement for every year almost half of Canadian generation. In 2011, these offices gave an account of site GHG outflows of 4.36 Mt Co2, or 2.5% of Ontario's aggregate discharges of 171 Mt.8 Roughly 60% of the division's outflows originated from modern procedures (2.6 Mt of direct outflows from the calcination of limestone into clinker), with the rest of from fuel burning.

Broadly, the cement part lessened its CO_2 discharges power by 13% from 1990 to 2010. This lessening driven by enhancements in the clinker-to-cement proportion, an expansion in the warm vitality substitution rate and a 21% change in general vitality force.

The production of cement discharges ozone harming substance emanations both specifically and by implication: the warming of limestone discharges CO_2 straightforwardly, while the copying of non-renewable energy sources to warm the furnace by implication brings about CO_2outflows.

The immediate outflows of cement happen through a synthetic procedure called calcination. Calcination happens when limestone, which is made of calcium carbonate, is warmed, separating into calcium oxide and CO_2. This procedure represents ~50% of all discharges from concrete production.

Backhanded emanations are deliver by consuming non-renewable energy sources to warm the oven. Furnaces are normally warmed by coal, petroleum gas, or

oil, and the burning of these powers delivers extra Co2 outflows, similarly as they would in creating power. This speaks to around 40% of concrete emanations. Finally, the power used to control extra plant apparatus, and the last transportation of cement, speaks to another wellspring of aberrant outflows and record for 5-10% of the business' discharges.

Cement as a product assumes a fundamental part in the development of a country since it is a basic crude material for solid, which is a key crude material in key segments like foundation, development, business and private land. All-inclusive, concrete contributes around 5% of the aggregate Co2 outflows. Concrete is the second most devoured substance on Earth after water. Overall, every year, each individual on the planet devours three tons of cement. In India, the cement area is one of the unmistakable supporters of traditional and GHG outflows. In spite of the fact that there is no statutory commitment on organizations to quantify and report add up to air outflows in India, the arrangement of air emanation inventories can be valuable in inside organization benchmarking, open revealing, item profiles, and developing discharges exchanging. Sooner rather than later, it is additionally conceivable that such inventories will urge intentional activities to advance vitality proficiency and GHG emanations alleviations, particularly in substantial, composed mechanical divisions like cement.

Table 1: Country Wise Carbon Emissions from Cement Industry

Country	Cement production	C/C ratio	Primary intensity	Primary energy	Process carbon emission	Carbon emission/ energy use	Total carbon emission	Share of world total
	Mt	%	GJ/t	PJ	MtC	MtC	MtC	%
China	423	83%	5.0	2117	47.7	53.7	101.4	33.0%
Europe	181.9		4.1	749	20.0	15.3	35.3	11.5%
Italy	33.2	80%	4.5	150	3.6	3.2	6.8	2.2%
France	21.2	74%	4.1	88	2.1	1.5	3.6	1.2%
Germany	36.1	79%	3.8	137	3.9	2.8	6.7	2.2%
Spain	26.7	81%	3.9	104	2.9	2.5	5.5	1.8%
Rest-of-Europe	64.7	84%	4.2	271	7.4	5.2	12.5	4.1%
OECD-Pacific	151.3		3.5	533	17.6	11.0	28.6	9.3%
Japan	91.6	80%	3.1	280	9.9	5.7	15.6	5.1%
Korea	51.6	96%	4.3	220	6.7	4.6	11.4	3.7%
Rest of OECD-Pacific	8.0	84%	4.2	34	0.9	0.7	1.6	0.5%
Other-Asia	123.8		4.9	613	15.3	13.3	28.6	9.3%
Thailand	31.1	90%	4.8	148	3.8	3.4	7.2	2.4%
Taiwan	23.2	95%	4.9	114	3.0	2.5	5.5	1.8%
Indonesia	21.9	96%	5.3	115	2.9	2.4	5.3	1.7%
Rest-of-other-Asia	47.6	87%	4.9	235	5.6	4.9	10.5	3.4%
Middle East	111.2		5.1	563	13.8	12.0	25.8	8.4%
Saudi Arabia	16.0	87%	4.7	75	1.9	1.4	3.3	1.1%
Egypt	16.1	99%	5.8	93	2.2	1.9	4.1	1.3%
Iran	15.9	97%	5.3	84	2.1	1.6	3.7	1.2%
Turkey	31.9	90%	4.9	156	3.9	4.1	8.0	2.6%
Rest-of-Middle-East	31.4	87%	4.9	155	3.7	3.0	6.7	2.2%
North America	88.4		5.4	480	10.6	10.8	21.4	7.0%
US	77.9	88%	5.5	427	9.3	9.6	18.9	6.2%
Canada	10.5	88%	5.1	53	1.3	1.2	2.5	0.8%
EE/FSU	100.7		5.5	558	11.4	10.3	21.7	7.1%
Poland	14.9	82%	5.6	83	1.7	2.1	3.8	1.2%
Ukraine	11.4	80%	6.0	68	1.3	1.3	2.6	0.8%
Russia	37.2	80%	6.0	223	4.1	3.8	7.8	2.5%
Rest-of-EE/FSU	37.1	87%	4.9	183	4.4	3.2	7.6	2.5%
Latin America	97.4		4.7	462	11.2	8.2	19.4	6.3%
Brazil	25.2	77%	4.1	102	2.6	1.7	4.4	1.4%
Mexico	29.8	88%	4.5	133	3.6	2.5	6.0	2.0%
Colombia	8.3	82%	6.1	51	0.9	1.0	2.0	0.6%
Venezuela	7.5	87%	5.7	43	0.9	0.6	1.5	0.5%
Argentina	6.3	90%	5.3	33	0.8	0.5	1.3	0.4%
Rest-of-Latin-America	20.2	87%	4.9	100	2.4	1.9	4.2	1.4%
India	62.4	89%	5.0	309	7.6	8.2	15.8	5.1%
Africa	41.0		4.9	201	4.9	4.2	9.0	2.9%
Morocco	6.3	85%	4.8	30	0.7	0.8	1.5	0.5%
South Africa	7.9	90%	4.9	39	1.0	1.0	1.9	0.6%
Rest-of-Africa	26.8	87%	4.9	132	3.2	2.4	5.6	1.8%
World total	1380.9	85%	4.8	6585	160	147	307	100%

(Source: CW Research 2020)

1.7 IMPACT OF CLIMATE CHANGE POLICY ON THE CEMENT INDUSTRY

Climate change policy has forced a circuitous cost on the vitality serious segments, for which vitality frames a critical offer of generation costs, which could negatively affect its intensity vis-s-vis outside and home makers. Vitality serious Industries are presenting to effects of discharges estimating approaches, and the limitations emerging from national atmosphere arrangements are a twofold edged sword. Steel, concrete, aluminum, essential chemicals, mash, and paper speak to the exemplary areas of industrialization and rising expectations for everyday comforts. Nevertheless, they likewise speak to the biggest wellsprings of vitality utilizations and GHG (Droege, 2o13). Internationally, aluminum, concrete, iron, and steel related organizations confront a hazard because of the environmental change approach (Baron et al., 2oo7).

1.8 COVID-19 PANDEMIC'S IMPACT ON THE SECTOR

The pandemic's full effect on the sector is currently difficult to predict because the long-term impact of the outbreak on the global economy remains unclear. However, in the short-term, direct effects on the cement industry are becoming clearer.

Effect on demand: In 2020, global cement demand is shrink to 3 percent year-on-year when including China, and 6.4 percent year-on-year when excluding China (On Field Investment Research 2020). Overall, the pandemic's impact will be unevenly distribute, with some countries more resilient than others will.

Utilization rate: Before the pandemic, the industry was not operating at full capacity; with the global economic slowdown, plants are expecting to see further drops in utilization rates. The global average utilization rate, which refers to producers' actual output over potential output based on fully utilized production capacity, could fall as low as 60 percent for 2020 according to projections, from about 70 percent annually over the past five years (Roger 2020). While companies are likely to finish committed expansions that were delay due to lockdowns, whether they start new projects beyond 2021 will depend on the pace of economic recovery.

Stock prices and foreign exchange risks: Over the last 12 months, share prices of major cement producers have fluctuated by an average 47 percent between their 52-week high and 52-week low (Share price declines were calculated using publicly available data for five top cement companies). Fluctuations in foreign exchange rates

have further eroded profit margins of cement companies in some emerging markets, and increased these companies' energy costs and cost of servicing debts in hard currencies.

Response to the Crisis: The cement industry considered an essential sector in most countries. Thus, companies have continued to operate through the pandemic, focusing on complying with health and safety requirements while protecting their own financial health. Meanwhile, governments are expecting to take proactive actions to support the industry.

Short-term actions: Companies are taking steps to protect cash flow and strengthen their financial position amid decreased demand, including: i) achieving cost savings by minimizing nonessential expenses and reducing labor costs; ii) cutting capital expenditures by postponing ongoing projects where possible and restricting maintenance to critical projects; iii) preserving working capital by adjusting inventory levels to market conditions and through other strategies; and iv) boosting liquidity by withdrawing credit lines and suspending dividends payments and share repurchase programs, among others.

Health and safety compliance: Companies are ensuring that plants comply with new health and safety regulations and standards set by governments in response to the pandemic. Generally, work can be perform with a high degree of safety because of plants' tightly controlled work environment, low personnel density, and the fact that much of the work takes place outdoors.

Merger and acquisition activity: In the short term, M&A activity is expect to be constrain as deals will be more difficult to complete. However, in the medium term, large, well-capitalized companies could seek to acquire smaller companies that are struggling due to the pandemic.

Government support: In some countries, the cement sector could benefit from government policies, such as those seeking to stimulate demand by promoting the housing market (e.g., facilitating easy access to home financing or supporting affordable housing projects or other public works). Whether governments introduce such interventions will depend on the broader challenges facing each country and the importance of the cement sector to the economy.

1.8.1 Going for ward

Once countries begin to reopen post-pandemic, consumption of cement and concrete is expect to gradually recover, fueled by economic growth, urbanization, and population growth, especially in emerging markets. The industry's biggest challenges and opportunities are longer-term: To survive and flourish, companies must prioritize sustainability and raise their environmental standards. Governments, investors, and the public increasingly are pushing companies to reduce their carbon footprint. Cement companies that prioritize sustainability even during this difficult period are likely to emerge as the winners in the next cycle. Many companies are already taking significant measures towards decarburization.

Decarburization goal: Globally, the cement industry has been moving towards decarburization. In the wake of the Paris Agreement, which aims to restrict any global temperature increase below two degrees Celsius from pre-industrial levels, the European Cement Association has set a target to reduce specific greenhouse gas emissions by about 30 percent (This percentage includes electricity. The data is from "Cementing the European Green Deal" - Cembureau 2020) by 2030 from 1990 levels. The ultimate goal is to achieve zero carbon emissions across the cement and concrete value chain by 2050.

Experts believe this 30-percent reduction can be achieved if the industry can make significant progress in: i) reducing the global average specific-energy consumption to 2.9 gigajoules/ton for clinker production and 80 kilowatt-hours/ton for cement, and targeting an average clinker-in-cement ratio of 65 percent by 2050; ii) rolling out full-scale waste- heat recovery, with a goal of achieving 100-percent alternative fuel use (half of which would be biomass) and over 50-percent renewable energy supply; and iii) scaling up innovative, low-carbon cement products and carbon capture, storage, and utilization technologies.

Public-private effort: Decarbonizing cement requires significant financing to pay technologies to reduce fossil fuel use and greenhouse gas emissions. This will require leveraging long-term public and multilateral financing with adequate private capital return. Government support is also critical. Joint efforts are expected to focus on: i) sharing R&D and pilot-project costs with a high degree of public funding; ii) introducing “greening” construction codes and standards not only for cement but also for the broader construction industry (such as green building), which can help stimulate growth and investment in the market; iii) introducing carbon pricing

mechanisms as appropriate; iv) promoting resource- and energy-efficiency measures and related technology transfers; and v) rewarding innovation, agility, and impact.

IFC'S Role: According to the United Nations, 3 billion people will need new housing and basic urban infrastructure by 2030. The International Finance Corporation (IFC) supports cement projects to help address this fundamental need in emerging economic, including in conflict and frontier markets. Furthermore, IFC supports base-materials production, including cement, to build domestic linkages to other sectors and increase economic complexity in emerging markets. IFC has invested more than US$3 billion (The figure includes both own-account investments and funds mobilized by IFC) in cement projects over the last 15 years across more than 25 countries.

IFC has launched a Sector Crisis Response Facility to provide urgent support for existing clients experiencing, or vulnerable to, the economic impacts of COVID-19. In the medium to long run, IFC seeks to support its clients in the manufacturing sector to increase product, process, and value chain complexity in emerging markets. Within the cement subsector, IFC is applying performance thresholds in the assessment of cement investments, and is supporting the industry to transition to zero carbon emissions through adoption of top-notch technologies that can help plants achieve high energy and resource efficiency. These include the installation of waste-heat recovery units, the production of blended cement with a lower clinker ratio, the use of alternative fuels and alternative materials (recycled, hence using circular-economy practices), and the implementation of carbon capture, storage, and utilization whenever possible.

Paradoxically, COVID-19 could accelerate the sustainability trend in the cement industry as the outbreak increases public awareness of health and environmental issues. The pandemic and ensuing global slowdown have presented new challenges for the industry but also new opportunities. Even as cement companies adjust to weakened demand, they can reset strategies to better position themselves once the market revives. They can also identify ways to raise their energy efficiency and reduce their greenhouse gas emissions, whether by adopting new technologies or by rethinking their products, portfolios, and partnerships. IFC partners with forward-thinking players to help them leapfrog technologies, deliver a lower carbon footprint, and emerge as the industry frontrunners of the future.

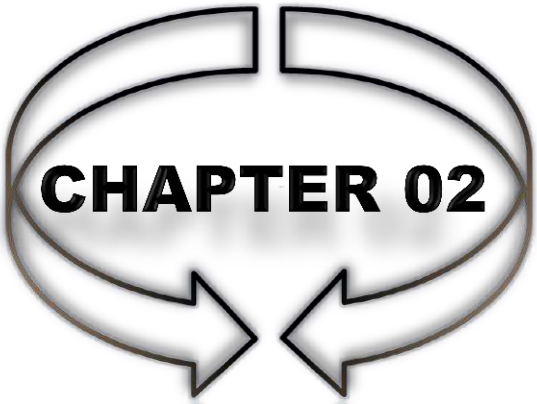
1.9 CONCLUDING REMARKS

Cement is consider as a binder, a material that is important in building and civil construction because it hardens and clings to other substances to form a bond. Cement is seldom use alone in construction, but is often use to bond other building materials together, such as gravel and sand. When combined with fine aggregates, it forms mortar for masonry, whereas when combined with gravel and sand, it forms concrete. As previously noted by, industrial energy, use accounts for between 30% and 70% of overall energy consumption in a number of chosen nations. Due to the high temperatures necessary in the kilns, the cement sub-sector consumes around 12–15 percent of total industrial energy. Cement is a critical component of contemporary infrastructure as well as the construction of safe and pleasant structures. Due to the high temperature necessary for clinkerization in the kilns, cement manufacture is an energy-intensive process. Coal, pet coke, furnace oil and natural gas are the principal fuels used in cement kilns. These solid, gaseous, and liquid fuels also provide the majority of the world's energy demand. While some of these fuels, such as coal and natural gas, may be use directly, others, such as petroleum, shale, and bituminous sands, need processing, refining, and distillation to provide usable fuels. Energy conservation is a critical first step in resolving the world's mounting energy crises and environmental damage. Developing nations, in particular, are interested in raising public knowledge of their countries' energy efficiency in terms of power production and consumption.

1.10 OBJECTIVES OF THE STUDY

Following objectives framed to approach current research:

1. To understand the existing Scenario of Cement Power Plant in India vs other countries.
2. To analyze & Compare with alternate source of energy as fuel for existing vs proposed processes.
3. To analyze the opinion of stakeholders for the Technical issue, Cost Issues, Environmental Regulatory Issues, Supply/ logistic Issues and Emerging Issues related to uses of coal as a fuel in cement power plants of Rajasthan state.
4. To study the scope of gravity for Natural Gas fuel on Cement Power plant in Rajasthan as an initiative by Government.



REVIEW OF LITERATURE

KEY HIGHLIGHTS

- *Research Papers and Research Gaps*
- *Concluding Remarks*

2.1 RESEARCH PAPERS AND RESEARCH GAPS

According to the phrase "literature review," a thorough analysis of past research on the subject at hand is called for. Research papers, books, and other sources relevant to one's field of study are routinely reviewed as part of an academic exercise called a literature review. This earlier study has to be included in the review in order to make it more thorough and comprehensive. Alternatively, a literature review is the act of gathering and analysing relevant material in a certain area of study with the goal of expanding one's understanding. Demonstrates scientific advancement by emphasising previous work, commonly accepted theories and current thinking in the topic. When writing a thesis or other kind of research paper, it is typical to include literature reviews to point out areas that have been overlooked in the field of study and to describe how a specific project fills in the knowledge gaps that were discovered. The current study followed up on the preceding literature evaluation by conducting a second one with the same end objectives in mind:

1. Cantini et al., (2021) approximately 7% of the world's industrial energy is used by the cement industry each year. A cement plant's energy consumption may be reduce by improving manufacturing technologies. Alternative solutions may be find on the market, as well as assessments of chances to enhance energy efficiency at an industrial cement factory, in the literature. Alternative solutions may be find on the market, as well as assessments of chances to enhance energy efficiency at an industrial cement factory, in the literature. It is the purpose of this article to describe the current and future use of new technology in the Italian cement industry. Based on their recent or planned implementation of energy-saving measures, a small sample of plants was examine via the study of an obligatory energy audit. For firms looking to enhance their environmental performance, this study provides a descriptive analysis. The findings show that auxiliary systems, such as compressors, engines, and pumps, are now the most appealing options for reducing energy use. These findings show that talking with industry professionals is an effective way to get new ideas for upgrading technology and so contributing significantly to scientific research efforts.

2. (Khan, Havukainen, & Horttanainen, 2021) It is estimated that cement manufacturing accounts for a large portion of world greenhouse gas (GHG) emissions. A possible approach for reducing cement production emissions is to employ alternative fuels, which may have an influence on emissions from the

waste management sector as well as from the cement manufacturing industry. Using solid recovered fuel (SRF) derived from commercial and industrial waste, this study explores the change in global warming potential (GWP) of ordinary Portland cement (OPC) production and the impact on waste management systems when conventional fuels are largely replaced by SRF (C&IW). It was decided to undertake a life cycle assessment (LCA) using a functional unit of one metric tonne of OPC production and the treatment of 194kg of C&IW. Between 2007 and 2016, data from an existing cement factory were utilised, where the percentage of SRF from total fuel energy demand rose from 0 percent to 53 percent between the years 2007 and 2016. Four different scenarios were develop, each with a different waste treatment technology and a different fraction of SRF in the thermal energy mix of cement manufacture. It was discovered that GHG emissions reduced by 20% from 1036 kg carbon dioxide (CO2), eq. (functional unit)-1 in Scenario 1 to 832 kg CO2, eq. (functional unit)-1 in Scenario 3, indicating a reduction of 20%. Furthermore, raising the percentage of SRF to 80 percent in Scenario may result in a decrease of 30 percent, or 725 kg CO2, eq. (functional unit)-1, compared to the baseline. In conclusion, the use of SRF in cement manufacturing may result in a considerable decrease in greenhouse gas emissions (GHG). Emissions might be decrease, particularly in middle- and low-income nations where trash is deposited in open landfills, without the need for large-scale expenditures in waste incineration facilities.

3. (Wojtacha-Rychter, Kucharski, & Smolinski, 2021)As a result of substituting coal for other fuels in clinker production, carbon dioxide emissions have been reduce. A total of seventy waste-derived samples of alternative fuels with a range of calorific values and a range of percentages in the fuel mixture were use in the computations. There were 543 Mg of CO2 emitted per hour from fossil fuel burning, based on yearly clinker production statistics and laboratory examination of the analysed fuels. However, when coal was completely replace with other fuels, the emission varied from 302 to 438 Mg of CO2 per hour, depending on the qualities of the fuel used. Net emissions decreased by 23% as a consequence of a 70% drop in fossil fuel use. Economically, the usage of alternative fuels as a supplement to gasoline has been shown to be beneficial. The averted CO2 emissions and the 136 megatons of coal saved amounted an average of 9718 euros per hour owing to the burning of 70% of alternative fuels with calorific values ranging from 15 to 26 MJ/kg. Cement kiln co-incineration

proved to be a long-term solution to reducing carbon emissions and lowering the cost of clinker manufacturing. It is possible that this study will serve as a starting point for further research and particular case studies on CO2 emissions reduction.

4. (Foundation, 2020) Indian economic development depends heavily on the expansion of its industrial sector, and cement is by far its most manufactured product. In 2018-2019, India's cement industry has an installed capacity of 545 million tonnes, making it the world's second-largest cement manufacturer behind China. Another factor driving India's increased demand for cement is the Smart City Mission, Housing for All, and other government initiatives such as the Pradhan Mantri Gram Sadak Yatra and the Urban Transport Metro Rail Projects. Environmentally harmful Green-House Gas (GHG) emissions are also associated with this increasing demand for cement. The cement business in India is one of the most difficult to reform since, despite great improvements in energy efficiency, GHG emissions from the industry are still much higher than the country's other major industrial sectors (187 million tonnes of CO2e in 2015-16) indian-GHG-platform-2016. India's cement sector must go beyond energy efficiency in order to meet the Paris Agreement's goal of keeping global temperatures from rising by 2°C by the end of this century. Energy usage, fossil fuel burning, and conversion of limestone into lime (industrial process and product use) account for 13 percent, 31 percent, and 56 percent of GHG emissions in cement manufacture, respectively (CII, 2010). Reducing the cement's clinker concentration is one way to cut down on emissions from the process. LC3, composite cements, geopolymer binders, belite rich cements, and other new cements have all been the subject of much recent study and development, Belite rich cements, geopolymer binders, and other new cements. In terms of CO2 reduction, composite cement has a potential of 56%, while LC3 has a potential of 30%. LC3 is now in production, while composite cement is in the last stages of development. in India's development. Furthermore, geopolymer concrete, which has the potential to reduce CO2 emissions by up to 80%, is still in its infancy. Currently, all the other possibilities outlined in the paper are in different phases of development. It is possible to reduce emissions by replacing the clinker in the final cement mix with Secondary Cementitious Materials (SCMs) such as fly ash, slag, and pond ash, as well as fillers (low-grade limestone). Additionally, the use of technologies like "Smart Crusher by" to recover cement from C&D waste will

reduce the requirement for new cement. It allows for the segregation of hydrated cement, unhydrated cement, sand, and gravel from the C&D waste. It is also possible to reduce the amount of cement needed for building projects by optimising design and using innovative construction methods. Bubble decks and voided concrete slab technologies may cut cement requirements greatly without affecting the strength of the slab. It is possible to design buildings that can be readily dismantled and reused in multiple uses by using the design for deformation technique. Using limited masonry and wood in the construction of buildings has the potential to reduce cement use, too. As a result, there are a number of ways to reduce emissions from the Indian cement sector that have been describe in this paper. It is necessary to examine the viability of each alternative low carbon material choice, substitute materials, and design & construction optimization methodologies in further depth. Standards need to be developed, the user community must be educated, and an environment must be built to facilitate speedier replication.

5. Mokhtar & Nasooti, (2020) the cement industry is a major consumer of electricity. Almost 15% of all industrial energy is use in this process. This industry has implemented a slew of energy saving programmes and strategies. A cement plant's technical and non-technology restrictions must be taken into account in order to execute the best possible solutions. A lack of attention on the plant's existing state and current conditions has resulted in a lack of focus on objectives such as energy savings, investment, and emission reductions. This research presents a three-phase strategy to handle these issues and help plant managers choose and invest in the best projects. It is a hope that the multi-criteria decision approach behind the proposed tool would aid cement managers in attaining their energy savings goals. For each of the three test instances, the programme generates a prioritised list of potential possibilities for each of the plants.

6. E&Y , Gas market in India 2020 -- Future outlook and Overview of India’s gas market Demand and Supply gap of natural gas in India, initiatives been taken by the Indian government that will prompt to increase in Natural gas utilization. The report did excluded whether the activities done by Indian government will have any effect on economic development of India

7. PNGRB --"Vision 2030" Natural Gas Infrastructure in India (2020). To convey current utilization/demand elements to evaluate demand of gas in different sectors & how to meet and framework projections, this will be required for same cause. Increasing consumption is foreseen to be complemented by modification in the primary energy mix of India of substitution of oil by natural gas. The report did not convey whether the increasing gas demand have any impact on development of India.

8. Shodhganga, Indian cement industry (2020) —an overview and profile of select cement companies. Indian Cement Ltd is the main assembling segment in India. Our nation is the second biggest maker of concrete on the planet. Concrete generation expanded at a compound yearly development rate (CAGR) of 9.7 for each penny in the period from 2006 to 2013, delivering 272 million tons (MT). The creation limit is anticipated to achieve 550 MT by FY 2020. The concrete business has been growing because of the expanding framework exercises and request from the lodging division. The bond business will profit by the declaration made in the Budget 2014-15 for focusing more on streets, metro rail ventures and urban foundation.

9. KPMG, Natural Gas (2020) – the road toward cleaner and prosperous future, Natural Gas Pipeline density.

10. Sadala et al., (2019) a crucial economic and environmental challenge, with the ever-increasing rates of waste creation, the treatment and disposal of industrial waste has emerged. Indian industrialised nations generate over 7.4 million tonnes of hazardous waste per year, of which approximately 3.98 million tonnes are recyclable for resource or energy recovery. These industries are key contributors to the country's economy and GDP. Indian scenario for the use of alternative fuel and raw material is less than 1 percent, despite the fact that there is an enormous quantity of hazardous waste that might be used in the production of alternative fuel and raw material. Using hazardous waste as an alternative fuel and raw material in cement kilns, The Netherlands accounts for around 83 percent of all hazardous waste generated. Human and animal health are jeopardised as a result of uncontrolled waste management, which impairs the quality of the environment's soil, groundwater, and air. Industrial waste is currently disposed of in landfills after being incinerate, rather than being used to its full potential via recirculation, as is common practise. The existing state of the treatment facilities was investigate in order to achieve a sustainable

management system that uses waste as an alternative fuel and raw material for the disposal of hazardous waste. Hazardous wastes may be utilised as a replacement for fossil fuels and/or raw materials in a few kinds of businesses, thanks to the notion of alternative fuels and raw materials. This will undoubtedly improve the efficiency with which industrial wastes are recirculate. It provides an overview of hazardous-waste generating industries in India as well as information on their locations, the potential of wastes as alternative sources of fuel for other industries, the use of alternative fuels and raw materials by the cement industry, and the regulatory requirements that must be followed.

11. Adeyanju & Okeke, (2019) the purpose of this article is to provide light on the environmental consequences of emissions from the cement manufacturing process. As a result of many studies, it has been shown that nations in Sub-Saharan Africa suffer the most from environmental pollution, particularly air pollution. One of these contributing aspects is the pattern of behaviour of employees and merchants who live in close proximity to manufacturing facilities. Additionally, data is not readily accessible in this location, which is significant. With the growing need for cement, combined with a surplus of locally sourced raw materials and a desire to include more regionally sourced resources, the number of cement factories has increased significantly. Air contaminants are present in varied concentrations throughout and around the cement factory. They have an impact on the lives and well-being of employees, children, and members of nearby towns, as well as the environment and wildlife. A number of diseases, including chronic obstructive pulmonary disease (COPD), silicosis, premature birth (psych asthenia), endocrine disruption, cancer, and infertility, are related with these pollutants. Specifically, this study discusses the effects of these contaminants on human health and plant development, as well as the areas where future research should be concentrated. These studies were picked from a large number of high-impact papers, and their coherent findings as they relate to different types of individuals were addressed in detail. Increased data collection, pollution characterisation, risk assessment, and dispersion analysis should be carried out in developing nations, according to the World Health Organization. More study should be conducted to understand the influence of alternative fuels and the efficacy of dust control methods already in use in different cement manufacturing facilities.

12. Hemidat et al., (2019) Bio-drying technology might be utilised to produce RDF from mixed municipal solid waste that could be used as an alternative to the conventional fuel now used in Jordan's cement plants, according to this experimental study. An analysis was performed to determine the RDF's properties and compare them to benchmarks established by several European nations. An RDF economic model was developed for the cement sector. To replace the petcoke fuel that is presently utilised, the model suggests six possible outcomes. RDF usage in the cement industry might save the business money and reduce greenhouse gas emissions, according to a cost-benefit study. The amount of dried garbage sent to the landfill was decreased by 35% as a result of the bio-drying process. The bulk of garbage to be land filled was decreased by 69% when RDF components were recovered from dry waste. Because of the decrease in waste moisture, the bio-drying method increased the waste's heating value (LHV) by 58%, reaching 15.58 MJ/kg. Calorific value was high; water content was low; and chlorine content was good. Heavy metal concentrations in RDF samples examined were lower than limits established by various European nations, according to the results of the tests. In cement kilns, using 15% RDF as a replacement fuel saves 486 USD/h in pet coke prices and emits 2.27 tons/h of CO2 into the environment, for a net savings of 389 USD/h, equivalent to 4.92 tons/h.

13. Bhatnagar & Khandelwal, (2018) There are 455 MTPA installed capacity and 285.68 MTPA actual cement output in the Indian cement industry, the second-largest manufacturer in the world, as of 2017. The state of Rajasthan has a cement manufacturing capability of around 30 MTPA. This includes Ultratech, ACC Lakheri, Ambuja and Shree cement facilities as well as India cement, Shriram and India Cement. India's yearly cement output increased from 95 Mt to 220 Mt between 2000 and 2010, a nearly 10% annual growth. Between 2010 and 2050, India's population (now 1,2 billion) is expected to grow by over 40%. (1.7 billion). A rise in GDP of USD 4,060 billion in 2010 should be followed by a rise of USD 37,721 billion in 2050 as a result of the recent fast urbanisation. Due to these trends and predicted large-scale infrastructure projects like new motorways, ports, dams and airports the demand for concrete is expected to rise. Additionally, there is expected to be a significant increase in the demand for concrete as a result of these developments. The demand for cement in the United States is predicted to rise at a rate of between 465 kilogrammes per capita and 810 kilogrammes per capita by the year 2050. Between 780 and 1,360

million tonnes of cement will be produced each year by 2050, depending on the "low demand scenario" and the "high demand scenario." India might become the world's leading cement manufacturer by 2050 if demand is strong. To avoid significant increases in greenhouse gas emissions as a result of these growth estimates, significant efforts are needed to make low-carbon technology and methods the standard in cement manufacture in the future. Rajasthan Cement Industries has also taken steps to lower its carbon footprint by implementing the best possible technologies and environmental practises, which has resulted in a reduction in overall CO2 emissions to an industry average of 0.719 tCO2/t cement in 2010 from 1.12 tCO2/t cement in 1996. To further minimise CO2 emissions, four technical important levers have been identified. Increasing the usage of AFR, improving thermal and electrical energy efficiency, reducing the clinker to cement ratio, and implementing newer technology are some of these levers. A plant's emissions may be reduced by using waste heat recovery for power production, as well as captive power generation. In February of this year, the Indian cement sector unveiled a low-carbon technological roadmap. There are other technical, financial and regulatory issues that need to be solved in order to make this a reality for the sector. Ultratech and ACC are both using AFR in their solar power facilities. A 45 percent reduction in cement emissions by 2050 may be achieved by using these specific levers in the International Energy Agency's 2 degree scenario (2DS) and 6 degree scenario (6DS) with suitable policy efforts and interventions. In the suggested roadmap, 10 percent of the emissions reduction potential is attributed to AFR usage, 4 percent to efficiency gains, 45 percent to blending increase, and 41 percent to innovative technologies. The WBCSD's Cement Sustainability Initiative (CSI members represent around 65 percent of India's cement production capacity) and the International Energy Agency (IEA) contributed significantly to this multi-stakeholder initiative. CII and NCB (developing technical papers and providing inputs to the roadmapping process) were also involved (bringing in a financial perspective, technical expertise and financial support).

14. Venkitasamy, (2018) Lakshmi Cement Ltd is part of the JK Group, which owns the JK Group. IIM-Ahmedabad released research in 2010 that found JK Lakshmi Cement Ltd to be the firm with the lowest carbon footprint in terms of kilogrammes of CO2 equivalent per tonne of clinker and rupees of revenue. With its own environmental standards at the top, the corporation also actively

engaged its workers and played an important role in social ties. Macro and micro environmental elements were present in the units. Elements like rainwater collection systems and packaged STPs are examples of macro-scale environmental features. A few examples are covered conveyor belts, covered vehicles, automated systems, the re-use and recycling of obsolete and unused materials, and the usage of green building materials on a smaller scale.

15. Census of India, District census handbook (2018), It gives information about urban and rural population in all tehsils of Dehradun district and also provides information for different types of fuels being used in both urban and rural households.

16. Husain Ahmad 2017, Demand Assessment and Design Aspect of City Gas Distribution Network, Demand assessment Pipe natural gas Compressed natural gas Distribution network CNG station CNG kit CGD technical initiatives. Risk accessed in CGD network wasn't clearly described.

17. MSME (2017), Brief Industrial profile of district Dehradun, It provides information about all types of industries in Dehradun district and growth rate.

18. Arbind Sircar, 2017 City gas distribution an Indian perspective. The report has analysis of city gas distribution industry in various parameters such as pricing, infrastructure regulatory and financing.

19. PWC, 2017, Oil and gas play, The report gives the details of supply, infrastructure development, policy regulatory reforms, developments in LNG and introducing sectoral reforms for accelerating gas usage.

20. Baidya, Ghosh, & Parlikar, (2016) Cement manufacturing accounts for 9.10 percent of overall industrial energy consumption, ranking it as the third biggest energy user in the world. Cement creates around 0.7–0.93 tonnes of CO2 each tonne of cement produced, depending on the kiln technique utilised. Cement production in the top ten cement producing nations, as well as the European Union, accounts for 1445 million tonnes of CO2 emissions each year. As a result, increasing attention is being paid to various carbon reduction measures. In order to make the cement production process a low-carbon process, co-processing is considered to be one of the most significant approaches. Based on the current research and two case studies, the paper reveals that a cement factory in India has the capacity to produce low-carbon cement while also addressing economic and environmental sustainability

considerations. Because conventional fuel and raw materials are conserved, co-processing results in a low-carbon cement production process, but at the same time trash going to the landfill is avoided, making co-processing a comprehensive methodology for resource recovery.

21. Baidya et al., (2016) Waste management is a severe problem in many parts of the globe. It is particularly prevalent in poorer nations. Another issue is non-hazardous industrial waste, which accounts for 100 million tonnes per year in the United States, with coal ash accounting for 70 million tonnes per year in India. It is the second most common kind of waste stream to end up at a landfill site with rising industrialisation, it is expected that the quantity would expand at a quicker pace in the next years. The properties of this industrial trash are similar to those of municipal solid waste, with a larger proportion of non-biodegradable garbage. In this waste stream, co-processing for energy recovery and as an alternative raw material in the cement industry may be an efficient waste stream management approach. This is being done in a number of nations on a long-term basis, but in India, the procedure is not being well implemented. In addition to having less auxiliary technology requirements, the method is very cost-effective and efficient. For example, this research demonstrates how successful co-processing in cement plants can be as a means of maximising the use of renewable energy sources and recoverable raw materials that are locked up in industrial waste. The resilience of co-processing of industrial waste has been investigated via the use of three case studies in the Indian context. Findings from the study revealed that it can be among the most effective industrial waste disposal techniques in India and other developing countries when compared to other practises of waste disposal methodology in terms of zero ash generation, emission reduction, reduced auxiliary technology requirements and lower set up costs, among other characteristics. Moreover, the economic and environmental statistical analyses demonstrated that co-processing is a reliable waste disposal approach in both urban and rural settings. Co-processing as an energy and material recovery method is shown to be sustainable in this research, which also tackles challenges connected to sustainable management of industrial wastes. Although a large number of research are accessible in the literature, analysis based on several case studies that are particular to the Indian environment is rare.

22. Indian gas sector survey 2016, To cover numerous aspects of gas sector by using survey methodology of industry members that serves useful inputs for making of policy. Development in LNG, infrastructure development will be created due to increasing gas consumption. The report does not indicate that all the development will have any impact on economic development of India.

23. Oxford Institute for Energy Studies (2016), Natural Gas in India: An Analysis of Policy. The report gives the brief about the energy in the Indian economies, political factors of hydrocarbon sector, policies involved in gas utilization and pricing.

24. HDFC Bank Investment Advisory Group, August 12, 2016, Oil and Natural Gas: City Gas Distribution, The share of natural gas in India's energy basket has increased from 5% in 2000 to ~7% in 2016. The major consumers of natural gas are the companies in Fertilizer and Petrochem/Refinery business which accounts for over 30% (each) of the total demand in May 2016. The paper gives an overall perspective of Industry background, Pipeline natural gas, Compressed natural gas Industry piped gas, also about the key factors in determining the demand of natural gas.

25. Rohit Bansal, 2016, Financial analysis of selected Indian gas distribution companies during 2009-2013, The study explores current city gas distribution companies and their financial structure.

26. Anirbid Sircar, Shreya Sahajpal, Kriti Yadav, 2016, Challenges and issues in natural gas industry, It gives a overall scenario of city gas distribution companies challenges and issues that they are being faced right now.

27. PR Newswire, 2016, India City Gas Distribution Market By Type, By CGD Allocation, Competition Forecast & Opportunities, 2013-2030, This report elaborates the opportunities for CGD companies in India.

28. PWC, India Gas Sector Survey 2016, Enablers for CGD development, Reforms for accelerating gas use.

29. Pareek & Pincha, (2015) Although India's cement business is internationally competitive because to favourable developments such as cost management, ongoing technological upgradation, and increasing building activity, the sector is nevertheless experiencing certain challenges. Alternative fuels, particularly bio-energy, are increasingly being used by major cement makers in India for

the combustion of their kilns. This is not only assisting cement businesses in lowering their production costs, but it is also proving to be successful in cutting emissions. With the continuous expansion of industrial operations, real estate, building, and infrastructure, as well as the establishment of numerous Special Economic Zones (SEZs) around the nation, the need for cement will continue to rise.

30. (Gollagari Ramakrishna, 2015), An empirical analysis of energy consumption and economic growth in India, To find is any causal relationship between GDP and energy consumption using Vector Correction. GDP and Energy consumption are bi-directionally related. Method. Study was carried in 2015 by using data from 1981-2010.

31. Indian Minerals Yearbook 2015, Government Of India Ministry Of Mines Indian Bureau Of Mines. The power of Cement Industry would proceed as bond stays vital for the improvement of foundation everywhere throughout the world and no other material would potentially substitute it sooner rather than later. Foundation and modern movement, land business and interest in center divisions for the most part drive the interest for bond. Some developing zones for bond request are solid streets, solid waterway lining and rustic development (lodging). More than 65% interest for bond emerges from Construction Sector.

32. University of Bologna, Natural Gas pipelines distribution (2015). The paper shows an overview of general characteristics, design, maintenance and hazards of natural gas transportation systems. Paper analysis starts from the description of the natural gas distribution systems, which represent the final section of the natural gas transportation. Since accidents on distribution gas system could threaten the urban safety, risk analysis needs to be assessed. For this purpose, the main hazardous consequences that may happen after a failure of the natural gas pipeline are defined. Correct design, installation and maintenance are required to reduce both frequency and impact of these accidents: a brief description of the principal technical requirements is reported.

33. U.S. Department of Energy (2015), Natural Gas Infrastructure Implications of Increased Demand from the Electric Power Sector, The purpose of this study is to understand the potential infrastructure needs of the U.S. interstate natural gas pipeline transmission system under several future natural gas demand

scenarios. Specifically, three scenarios were developed: a reference scenario and two scenarios with increased electric sector natural gas demand. Both increased demand scenarios—an Intermediate Demand Case and a High Demand Case—are based on a simple, illustrative national carbon policy applied to the electric power sector (not based on any real or proposed policy) that drives increased electric sector natural gas use.

34. Alok Sharma- 2015, Challenges and Best Safety Practices in CGD Industry. There are various challenges during Laying of Pipeline as per relevant codes & statutes as obtaining permissions, clearances, NoCs, approvals, etc., availability & retaining of trained & experienced manpower, constraints in laying of pipeline in highly populated area, presence of other utilities, etc.

35. Shrivastava, Shrivastava, & Ganguly, (2014) The goal of this study is to examine how well the cement industry's green environment operations function operationally. Currently, cement firms are using green manufacturing techniques that include data collection, design, and control of production systems to reduce their environmental impact. An extensive survey and study was conducted, which collectively showed ways for identifying the most important influencers on green technology development. A thorough grasp of each case study technique and proportionate analysis is necessary in order to get insights into the progress of green technology initiatives. Global warming, gas emissions, water waste, and other wastes during the making of cement are discussed in a study article. This approach is quite different from previous ways in that it uses a green manufacturing style and has a bright future. For this article, the primary goal is a debate on the various approaches to cover the full product life cycle, from conceptual design to disposal, in a benign, safe manner that has no or low effect on the environment by maximising the use of resources and reducing waste.

36. Chaurasia, Ahmad, Gupta, & Kumar, (2014) In this study, data on the air quality in the Nambahera district of Chittorgarh in Rajasthan, India, is presented. New National Ambient Air Quality Standards were used to evaluate air quality. So2 and NOx emissions were included in the list of metrics. Near power plants and coal mills, the average PM10 value was found to be over the allowed level. The Air Quality Index (AQI) is the result of the investigation. Pollutant concentrations of PM10 and SO2 and NOx were determined to be below acceptable limits, according to the Air Quality Index

(AQI). Asthmatics and those who suffer from respiratory ailments are at particular danger, according to the results of the PM10 study.

37. Ministry of petroleum & Natural gas -- Annual Report (2014). To pass on essential statistical data identifying with physical attainment of the Oil and Gas industry in India. Utilization of natural gas from 2014 to current year with forecast of expanding gas demand. The report excluded whether forecast of continuously increasing gas demand have impact on the economic development of India

38. Indian Minerals Yearbook 2014, Government Of India Ministry Of Mines Indian Bureau Of Mines (i) Cement Industry in 2014, (ii) Growth drivers

39. University of Petroleum & Energy Studies (2014), Analytical Study of Natural Gas Pipeline Tariff, The research can be used to take strategic decisions in relation to investing in a natural gas pipeline with special emphasis on demand estimation and tariff determination. The research (demand and tariff) will be conducted keeping both prioritize (power and fertilizers) and no prioritize sectors (industries and CGD) in mind.

40. Government Of India Ministry Of Mines Indian Bureau Of Mines, Indian Minerals Yearbook 2014, (i) Cement Industry in 2014, (ii) Growth drivers.

41. Heijnen et al., (2013) India's economy is the third biggest in the world by GDP in purchasing power parity, however while having a massive population, it ranks only 165th in terms of GDP per capita. After a period of gradual decentralisation, the economy has developed into a more varied market economy that is increasingly driven by an educated and business-minded middle class, which has been in place since the early 1990s. One example of this is India's now world-famous telecommunications and service industry, which has seen tremendous growth over the previous decade. Because of increased variety, India's agriculture has become less reliant on the country's agricultural output, while it still accounts for around half of the country's revenue. Manufacturing continues to be robust, accounting for more than a quarter of total production. Although India has had economic growth and progress in its service sector, income inequality continues to be a significant challenge for the country. In 2011, about one-third of Indians lived in poverty, and the country's ongoing population expansion made it difficult to raise living conditions. For example, India celebrated the arrival of its one billionth

resident in 2000. In the next 12 years, the world's population has grown to more than 1.2 billion people. Primary research was carried out in order to compile this MRP-1 report, and it was used to determine the performance of four large cement companies in terms of customer retention. We have also conducted financial analyses of four major players in the cement industry using secondary data for the last five years. These analyses include aggregate industry ratio analysis, separate company's ratio analysis, aggregate industry sales trend for the last ten years, and aggregate industry production trend for the last five years, amongst other things. Researchers have also conducted numerous analyses, such as "Porter's five-force model, operational theory, and PEST analysis."

42. Worrell, Kermeli, & Galitsky, (2013) Considering that energy accounts for 20-40% of cement manufacturing costs, energy efficiency is critical if the industry is to remain competitive and keep prices down. In the past, energy intensity has decreased, but it seems to have stabilised lately with the increases. Coal and coke have replaced natural gas as the dominant source of energy in the industry since the 1970s. Tires, among other waste fuels, are progressively increasing their percentage of total gasoline use.

    A reduction in primary physical energy intensity of 1.2 percent per year was seen in cement manufacturing between 1970 and 2010, when the energy intensity decreased from 7.3 MBtu/short tonne to 4.5 MBtu/short tonne. Fuel usage and raw material calcination reduced carbon dioxide intensity by 24%, from 610 lb C/ton cement to 469 lb C/ton cement to 0.23 tC/tonne cement. There is still a lot of space for improvement in energy efficiency, notwithstanding the advances made in the past. U.S. clinker output declined from 60% wet-process facilities in 1970 to 7% wet-process plants in 2010. Remaining plants point to a significant potential in comparison to other developed nations. Energy-efficient technologies and measures were analysed, with estimates of energy savings, CO2 emissions reductions and investment costs for each measure taken into account.

    The report describes the measures and experiences of cement plants around the world with these practices and technologies. The cement sector and individual plants have a lot of room for improvement in terms of energy efficiency. Modernization and expansion projects at existing facilities, as well

as new plant building, will help to realise some of this potential. Still, there is a lot of room for improvement when it comes to energy management.

43. (Sahbi Farhani M. S., 2013), Role of Natural Gas Consumption and Oil Trade in Tunisia's Output - To investigate the effect of real gross fixed capital formation , trade and natural gas consumption, on the real GDP of Tunisia To achieve the interpretation and objectives of the various tests. Study was done on Tunisia and not on India.

44. (Melike E. Bildirici, 2013), Relationship among Coal, Natural gas & Oil consumption and economic growth in BRICTS countries - To inspect of any causal relationship between natural gas, coal and oil consumption and economic growth for BRICTS (Brazil, Russian, India, China, Turkey and South Africa) countries. India had bidirectional causal relationship between economic growth and coal consumption. The study constituted coal consumption and was not specific for oil and natural gas consumption.

45. Confederation of Indian Industry, (2011) As of March 2010, India was the world's second biggest cement manufacturer, with a total installed capacity of around 260 million metric tonnes per year (MTPA). The cement business in India is a rapidly expanding sector, with an estimated increase in capacity of 92.3 million tonnes (MT) by the year 2013. Consequently, by March 2013, the cement industry will have a total installed capacity of 383.5 million tonnes per year (MTPA). The Indian Cement Industry accounts for around 7% of total global cement production. The current per capita use of cement in India is around 186 kg2, which is much lower than the consumption of cement in various other nations across the globe. India's GDP is expected to increase by an outstanding 9.2 percent in fiscal year 2011, and infrastructure sectors such as cement are expected to develop at a rate that is nearly as fast as the country's overall GDP.

    In terms of raw materials and fuels, the cement industry is a Resource-Intensive Industry (RII), requiring a considerable quantity of natural resources to operate. The global cement industry consumes approximately 3.84 percent of total global primary energy consumption, or nearly 5 percent of total global industrial energy consumption3. At the same time, known fossil fuels, and particularly coal, which is the primary fuel for the Indian cement industry, are rapidly depleting. It is imperia, to say the least! I'm going to seek for alternatives. Additionally, it is critical for all corporations to fulfil their social

responsibility towards sustainability by lowering their use of fossil fuels as well as their emissions of greenhouse gases. Furthermore, the supply of natural raw materials is decreasing significantly, and obtaining land with mineral resources, which are essential for the production of cement, is becoming increasingly difficult. The exploration of alternative resources such as fuels and raw materials is becoming more significant due to the rising demand for cement in the nation. The cement industry needs to be on the lookout for. On the other hand, waste management in India is becoming a growing source of worry. The expanding urbanization and fast industrial expansion in the nation are resulting in a significant increase in the quantity of Municipal Solid Waste (MSW) and Industrial Wastes generated (both hazardous and non-hazardous), substantial posing! Significant difficulties in managing the same owing to the country's scarcity of infrastructure for managing the same. Urban Waste Management has also been identified as a critical component of environmentally sustainable economic growth in the Prime Minister's NAPCC - NMSH4.

46. Muller & Harnisch, (2011) Impacts on the climate of the cement industry's emissions As a global community, we've come to accept that climate change is a genuine concern. Global action is required to reverse the upward trend in global emissions of greenhouse gases. During the next ten years, global emissions levels should fall by 50% from 1990 levels by 2020. Global warming will be limited to 2°C in the 21st century as a result of the so-called 450 ppm stability scenario. These goals are gaining traction, even on the international policy stage. Their implementation is almost certain in talks under the auspices of the UN.

    Approximately 6% of all human greenhouse gas emissions were attributed to cement manufacture by the year 2006. Cement-related emissions are predicted to rise by 260 percent between 1990 and 2050, despite major improvements in efficiency. Because of this, the difficulty of transforming the old method of cement production into a sustainable business model and how measures to decrease emissions from the cement industry may be implemented in a timely manner emerges.

47. Madlool, Saidur, Hossain, & Rahim, (2011) Cement production accounts for 12–15% of overall industrial energy use. A current analysis of energy usage and savings is thus required in order to detect energy loss and put in place the

necessary steps to minimise energy consumption in this industry sector. Details of the cement production process, as well as numerous energy-saving strategies that may be used in the cement industry, have been studied and provided in this study. The quantity of energy that may be saved as well as the implementation costs of various energy-saving methods were rigorously assessed. In addition to the decrease in CO2 emissions and the payback time for various energy-saving initiatives. Thesis, peer-reviewed journal publications, conference proceedings, books, reports, and websites were analysed in this research. China is the world's largest producer of cement, accounting for a significant percentage of global output. Coal is a major energy source for cement plants. Industries, on the other hand, are increasingly turning to alternative fuels in addition to traditional ones in an effort to minimise pollution. According to a survey, cement businesses are shifting from wet to dry processes since they use less energy.

48. Israt Mustary, Harun Chowdhury, Bavin Loganathan, Firoz Alam, 2010, Development of a computational model for optimal sourcing of LNG. This talks about constructing a model for sourcing LNG at the minimum possible price. It does not give information on contract formulations and price renegotiations.

49. Frank C. Graves Steven H. Levine, 2010. Managing natural gas price volatility, principles and practices across industry. This paper gives details of different trading strategies used by LNG buyers in different time frames. This paper doesn't provide details on how to structure nonstandard contracts.

50. VIKALPA Volume 35 October - December 2010, (D J Pandian, L Mansingh, L K Singhvi, Sridhar Tambraparni, B S Negi, Shaleen Sharma, Allan Perrin) City Gas India Roundtable 2010: Initiatives and Challenges, City Gas Distribution: Infrastructure and Operations Perspective, Issues in Development of Gas Markets, Issues in the Development of the CGD Sector, Health, Safety and Environmental Issues, Market Development Strategies.

51. Zainudeen & Jeyamathan, (2008) In Sri Lanka, cement is a common building material. For both construction and infrastructure development, Sri Lanka has a strong need for cement. Pre-production phases of cement manufacture have considerable environmental impacts. This research examines the environmental effect of Sri Lanka's cement manufacturing process. Cement manufacture was found to use a dry method at Puttalam Cement Company

Ltd. (the sole cement manufacturing plant to comprise all stages of production), according to a case study. In addition, the research found that 4-5 percent of the kiln feed's dust emission was responsible for the various sources of dust emissions, including crushers, grinding clinker coolers, and material handling equipments. As shown in the case study, the primary sources of CO2 emissions are the burning of fuel and the formation of clinker in the kiln, which is a step in the cement manufacturing process. A tonne of clinker produces 0.613 tonnes of CO2, according to the research.

52. (Asghar, 2008), GDP-Energy relationship: Causal analysis for different five countries of South Asia – To explore of any causal relationship between GDP and distinctive types of energy utilization for the five South Asian Countries; Nepal, Sri-Lanka, Pakistan, Bangladesh and India. For India, no causal relationship was found between GDP and types of energy consumptions. Study was not limited to Natural gas intake; consideration all types of energy utilizations was done. Study was done in 2008 with data up to 2005.

53. Yessiva, Jan C. Bongaerts, 2008, Optimizing of revenues from trading LNG in different geographical spot markets. This paper tries to figure out the possibilities and problems associated with re exports of LNG in spot market. It does not provide ways for financing LNG projects under short term contracts.

54. Asthana & Patil, (2006) Extensive research and experience in a variety of sectors has shown that the use of waste as an alternative fuel for cement plants is both environmentally friendly and economically viable. However, there are a number of issues that must be considered prior to using alternative fuels. Furthermore, accessibility and affordability are crucial considerations. Studies of the literature and case studies have demonstrated that the use of tyre generated fuels in cement kilns is a technically and economically feasible option, alongside the use of other alternative fuels.

    As a result, the research recommends that discarded tyres be used in cement kilns in India to the greatest degree feasible to reduce emissions. Only a few cement mills have begun investigating the possibility of using tire-derived fuel in their facilities. However, owing to the authorities' inability to establish standards in a timely manner, they have not been able to move it to the application level yet. The co-combustion of alternative fuels would undoubtedly aid in the reduction of energy costs, hence offering a competitive advantage for Indian cement factories in the global marketplace. The backing

of the government and the actions of the private sector are both required for the adoption of alternative fuels.

55. Caruso, (2006) In the face of public pressure, governments throughout the globe have been compelled to address environmental concerns, and global warming is one of the most contentious. Under the United Nations Framework Convention on Climate Change, the Kyoto Protocol was established (UNFCCC). A number of nations signed up to the Kyoto Protocol's commitment to decrease their GHG emissions. There is a worldwide warming trend anticipated by the Intergovernmental Panel on Climate Change, and carbon dioxide is a primary greenhouse gas. Approximately 5% of the world's CO2 emissions are attributed to the cement sector.

    Since the Kyoto Protocol was signed in 1997, Canada has taken a fairly hard stance on reducing greenhouse gas emissions. While cement production and distribution are confined by geography and the availability of natural resources, major cement companies throughout the world will be compelled to fulfil increasingly severe environmental requirements as a result of global politics and international affairs. As part of Kyoto, nations are required to cut emissions by an average of 5.2% below their 1990 baseline. Between 2008 and 2012, this decrease must take place. Despite the fact that these limitations are country-specific, most nations are mandating businesses to set explicit goals for reduction. This is particularly evident in European nations.

    GHG emissions abatement solutions that are novel and ecologically benign may now be justified economically thanks to the credit trading opportunity. An Ontario cement factory, St Marys, was utilised as a test site to determine the effects of different operational improvements on the facility's CO2 emissions. St Marys Plant data was used to construct an economic model whose goal it is to highlight the optimal selection approach to cut CO2 emissions at the lowest cost. The St. Marys Plant achieved a considerable decrease in CO2 emissions per tonne of cement produce of 23.6 percent. Using a progressive approach to project execution, we were able to accomplish the desired objectives.

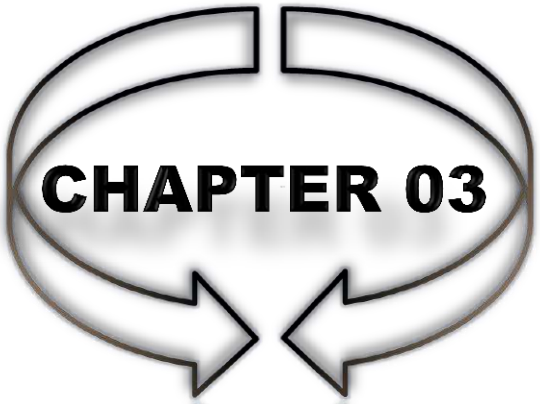
56. Coito, Powell, Worrell, Price, & Friedmann, (2005) The cement business in California employs between 10% and 15% of the state's workforce, making it the biggest cement producing state in the United States. There are 31 cement plants in California that use a lot of energy each year: 1,600 GWh of electricity,

22 million therms of natural gas, 2.3 million tonnes of coal, 0.25 tonnes of coke, and lesser quantities of waste materials, like tyres. Background information, an evaluation of energy-efficiency potential and challenges, and programme suggestions that may be utilised by programme managers to better target goods to the cement sector have been detailed in this case study. Customers' facilities were surveyed and interviews with decision-makers were conducted as part of this case study's principal methodology. It was also constructed a fundamental cement manufacturing process evaluation, and summaries of the cement industry's economic statistics were compiled. Background information about the cement industry and the identification of possible energy-efficiency improvements may be gained via secondary data analysis. The interviews provide light on the customer's opinion on the execution of energy-saving solutions.

57. Worrell, Price, Martin, Hendriks, & Meida, (2001) Cement production accounts for 5% of worldwide anthropogenic CO2 emissions, making it a significant target for CO2 emission reduction measures. Cement production. The calcination of limestone, the burning of fuels in the kiln, and the creation of electricity all contribute to the emission of CO2. Cement production generates a significant amount of CO2 emissions due to the manufacturing process as well as energy use. Data on process emissions is now the only information readily accessible. The cement industry's ability to reduce its CO2 emissions is also a topic of discussion. Carbon dioxide (CO2) emissions from cement manufacturing processes accounted for 160 MtC in 1994, while energy usage accounted for 147 MtC of total emissions. Cement manufacturing emitted 63% of the world's carbon dioxide emissions in 1994, according to the top ten cement-producing nations. Cement manufacturing throughout the world emits an average of 222 kilogrammes of carbon dioxide every tonne of cement. Alternative cements and the removal of CO2 from flue gases in clinker kilns are among the emission reduction alternatives that include increasing energy efficiency, implementing innovative processes, switching to low-carbon fuels, using waste fuels, and increasing the use of additives in cement production.

2.2 CONCLUDING REMARKS

After thorough assessment of prior studies, it was find out that there was few studies, which were trying to address use of natural gas or clean fuel in Captive Power Plants. Especially the PNGRB --"Vision 2030" Natural Gas Infrastructure in India increasing consumption is foreseenand to be complemented by modification in the primary energy mix of India of substitution of Coal by natural gas in Indian Captive Power plants. But the report did not convey whether the increasing gas demand have any impact on development of Indian Captive power plants of Cement Industries. The existing research try to fill this gap, made an effort through survey analysis and by applying quantitative analysis, and explore a research titled as "A Study of Feasibility in Rajasthan Cement Industries Power Plant on Usage of fuel (Natural Gas as Clean Fuel vs. Coal). The next chapter mentions about the research design and methodologies used in the research work.



RESEARCH METHODOLOGY

KEY HIGHLIGHTS

- *Overview, Statement of the Research Problem and Rationale*
- *Research Design*
- *Sampling Design*
- *Types of Data Used*
- *Designing of Tools for Data Collection*
- *Data Analysis Method*
- *Variables and Scale of the Study*
- *Hypothesis*
- *Limitations of the Study*
- *Concluding Remarks*

3.1 OVERVIEW

This unit of research work discusses methodology employed for this study. Usually the research type, factors of research and research goal are discussed briefly at the outset. Research Design under which Methods used, Sample Selection, Research Instruments & Pilot Study have been covered in this study. The approach for conducting reliability test is also illustrated in this chapter. It further contains description of statistical/mathematical methods employed; testing of hypothesis and limitation of the study.

3.2 STATEMENT OF THE RESEARCH PROBLEM AND RATIONALE

The history of human development depends on energy supply and usage. Development was facilitated by the shift from early utilization of fire, life-enhancing energy, to the present world by using electricity and cleaner sustainable fuels for a variety of reasons. Energy has a basic requirement, ranging from the cooking, heating, cooling, lighting, transportation and operation of equipment to ICT services and machinery in every sector in each country, but not restricted to them. The lack of access to reliable and clean energy is now seen as a major hindrance to human well-being. Energy systems which can meet the constantly rising requirements of developing economies are in urgent need of the hour. The need to shifting to cleaner fuels and better energy systems has led to increasing global energy needs in the heavily populated parts of Asia, particularly India. There is thus a push in India for increasing installed power generation capacity and reducing dependence on primary fossil fuels to address these demands.

At the heart of Indian policy planning has been the generation and delivery of sustainable, dependable energy at competitive costs by optimising the use of various energy resources with new environmental-sensitive technology. In addition, the environmental and health consequences of hydrocarbon consumption are forcing the globe into implementing renewable energy and energy efficiency technologies. Cement production is one of India's most energy-intensive and CO2 businesses. CO2 emissions also increase significantly with the development of cement manufacturing. The new technique for reducing CO2 emissions in the cement sector is the most practical capture and storage alternative. Further environmental impact study is necessary to provide the theoretical basis on which the carbon capture and storage in cement manufacturing may be implemented.

In Rajasthan, cement plants are more relying on fossil fuels. Increased use of renewable and alternative fuels can extend fossil fuel supplies and help resolve air pollution problems associated with the use of conventional fuels. Rajasthan has huge reserves of cement-grade and Steel-Melting-Shop (SMS) grade limestone. SMS-grade limestone from Jaisalmer is supplied to various steel plants in the country. Rajasthan has 24 major cement plants, having a total capacity of 55 million tonnes per annum (MTPA). It is the largest cement-producing state in India.

Though there are economic constraints and the proposal might not look feasible to the cement producing companies but still it is a very feasible outlook if natural gas is substituted. The only assumption that is critical to the study is that government will have to invest in the infrastructure build up in order to make this proposal a little bit worth the time of the cement industry. Also there are constraints of natural gas in availability in India and this could be a big bottleneck in the switching to natural gas but with many pipeline underway and many government initiatives to increase the availability of gas in the country make this a feasible proposition.

The onshore natural gas production in the Indian state of Rajasthan is expected to reach approximately 1.5 billion metric standard cubic meter per day during the fiscal year 2021. This was an increase from about 1.9 billion metric standard cubic meter per day in the previous fiscal year. In the light of this scenario shifting of industries on natural gas as a clean fuel in comparison of coal will be defiantly a significant step towards pollution free environment in accordance to international laws pertaining to environment protection. Hence the current study is an attempt to investigate feasibility of Cement industries power plants in Rajasthan while using Natural Gas as a clean fuel in comparison of coal.

3.3 RESEARCH DESIGN

Both **Descriptive and Qualitative** designs were employed by the researcher while carrying out this particular research work. A comprehensive literature review, backed by problem statement & study's purpose, and identification of variables, has provided researcher more insights into the topic.

3.4 SAMPLING DESIGN

3.4.1 Population

Theoretical universe is all cement plants operative in India. Rajasthan has 24 major cement plants, having a total capacity of 55 million tonnes per annum (MTPA). It is the largest cement-producing state in India. For current study, the study universe is 24 Cement plants as on year 2018-19 in Rajasthan State.

3.4.2 Sampling frame

List of Cement plants provided in annual report of IBEF report on Indian cement industry analysis 2019 and Indian Minerals, Year book 2019 Government of India Ministry of mines considered as sampling frame for the current study.

3.4.3 Sampling method and sample size

While choosing cement plants researcher has considered those only which have captive power plants on their manufacturing sites. Another parameter considered while selection of plants to be approached during primary survey were Installed capacity and Size of the plant. For selection of Cement plants Judgemental sampling was adopted and top 10 plants were finally considered for the primary survey as listed under.

1. *Ambuja Cements Ltd*
2. *ACC Limited*
3. *Binani Cement Ltd*
4. *Birla Corporation Ltd*
5. *India Cements Ltd*
6. *J.K. Cement Ltd*
7. *Mangalam Cement Ltd*
8. *Shree Cement Ltd*
9. *UltraTech Cement Ltd*
10. *Wonder Cement Ltd*

For calculation of sample size

S. No.	Name of The cement plant	Plant Size / Installed Capacity	Total questionnaire distributed	Responses received	%
1.	Ambuja Cements Ltd	29.65 MTPA	100	42	42%
2.	ACC Limited	1.6 MTPA	100	38	38%
3.	Binani Cement Ltd	6.25 MTPA	100	26	26%
4.	Birla Corporation Ltd	15.5 MTPA	100	48	48%
5.	India Cements Ltd	1.5 MTPA	100	29	29%
6.	J.K. Cement Ltd	10.5 MTPA	100	21	21%
7.	Mangalam Cement Ltd	4.06 MTPA	100	36	36%
8.	Shree Cement Ltd	43.4 MTPA	100	45	45%
9.	UltraTech Cement Ltd	1.5 MTPA	100	48	48%
10.	Wonder Cement Ltd	8 MTPA	100	54	54%
	Total		**1000**	387	38.7%

1000 stakeholder including Chief Business Officer, Dgm, Director, Dy Manager, Ex Director Operations, Executive Engineer, General manager Head HR and Admin, Management Consultant

Manager, Manager Sales, Mgmt officer, President Regulatory Affairs, Retired General Manager, Sr. Manager Operation and other key persons from concerned departments were approached during the primary survey by the researcher. In all 413 filled questionnaires were received. Following a thorough analysis of questionnaires, 26 data records were excluded due to lack of information and insufficient data. As a result, the final set of data contained 387 valid records. Hence **387** were considered as appropriate sample size for further analysis.

3.5 TYPES OF DATA USED

This type of empirical study demands the collection of both primary and secondary data. A set of structured questionnaire for stakeholders of cement plants was used to collect primary data. The opinion of respondents was measured on Likert's 5-point scale basis. The survey approach was used to acquire primary data. Desk / secondary research was used to acquire secondary data and then case studies were developed as per the requirement of qualitative analysis.

3.6 DESIGNING OF TOOLS FOR DATA COLLECTION

3.6.1 Questionnaire design

Questionnaire approach was employed for data collection since it is the best technique for obtaining vast volumes of data. Furthermore, respondents would have enough time to read, understand, and respond.

To collect opinion of teachers, self-structured Questionnaire was prepared with four sections.

Part I has been designed to capture information concerned with demographic properties of respondents, like Gender, Designation, Age group, Education, Size of Plant, installed capacity of the plant, Age of the plant and Type of Fuel used by plants.

Part II includes statements aimed at measuring the respondent's opinion for the issues like Technical issue, Cost Issues, Environmental Regulatory Issues, Supply/ logistic Issues and Emerging Issues related to uses of coal as a fuel in cement power plants of Rajasthan state. The respondents had been asked to indicate his response with 5 points Likert scale, where 1 stands for SD and 5 stand for SA.

For Qualitative Analysis Research has developed case studies and for the same evidences were collected from different cement plants shifting towards alternative

fuel in spite of coal and operational in North America, Nigeria, united states (U.S), and Japan.

3.7 DATA ANALYSIS METHOD

Detailed observational data was analysed and displayed in a simple table and appropriate charts were framed to explain the collected information purposefully. The assessment of data in the current study has been carried out utilizing simple statistical techniques such as frequencies, percentages, averages, etc. These are employed to meet desired research and data necessities. Appropriate statistical techniques of IBM SPSS 20 like; Descriptive statistics, Mann-Whitney U Test and Kruskal Wallis Test were utilized to check the previously mentioned hypotheses.

3.8 VARIABLES AND SCALE OF THE STUDY

The variables and constants have been chosen from previous research, or the scholar generated new variables and constants. The constructs/scales utilised in this study are based on past research in this domain.

Variables considered for study and accordingly their numbers are shown below.

	Variable	**No. of Items**
Issues related to uses of coal as a fuel in captive power plant in cement industry	Technical issue	10
	Cost Issues	6
	Environmental Regulatory Issues	5
	Supply/ logistic Issues	3
	Emerging Issues	6
	Total	30

3.8.1 Reliability testing of scale based primary data

Cronbach's Alpha is a valid and reliable measure of components in a survey form being used testing the reliability. It ranged from 0 to 1. The significantly larger the scale reliability of the questionnaire items, the relatively close alpha is to 1. Cronbach's Alpha (1951) is average of all possible split-half correlations is alpha 0. If two representative samples of components out of a pool, including those from the test item, are directly linked, the value estimated is termed as alpha. Nunnally (1978) mentioned that the consistency of the overall samples taken was determined through using "Cronbach alpha" that fulfilled the reasonable level criterion (>0.60). Schmitt (1996) asserted that modulation induces extrapolation of genuine relationship.Alpha levels that are adequate are defined by how the test is being used and viewed. Cronbach alpha is assessed by using number of components as well as the mean inters item correlation. Hinton and his colleagues (2012) whereas if Cronbach alpha value is larger than 0.60, the measurement can be deemed credible. The relatively high the Cronbach alpha value, the more credible the measurement is. Mallery & George (2011) Whilst also discarding the items in the scale one after the other, the significance of Cronbach alpha was ascertained. If removing an item diminishes the value of Cronbach alpha for rating, it appears to indicate that now the item being removed is significant and therefore should not be removed. This investigation is termed as "Cronbach alpha if item deleted".

To test the appropriateness of the research tool a pilot survey was conducted in two of the Plants situated nearby Jaipur Rajasthan. In all, 70 respondents approached with a semi-structured questionnaire to seek their opinion regarding various issues. For each construct, Cronbach's Alpha was computed and checked for the internal consistency of constructs. Researcher also approached subject matter experts and Professionals in the field of Captive power plants so as to ensure content validity of the data collection tool.

Cronbach's Alpha of pilot study

	Cronbach's Alpha	**N of Items**
Reliability Statistics for selected Issues	0.826	30

Item-Total Statistics				
	Scale Mean if Item Deleted	**Scale Variance if Item Deleted**	**Corrected Item-Total Correlation**	**Cronbach's Alpha if Item Deleted**
The calorific values of coal is lesser than natural gas	124.23	89.666	.245	.824
The stoichiometric air requirements of natural gas are greater than coal	126.02	102.287	-.446	.864
Natural gas mixes with the air and burns quickly as compared to coal	123.74	92.243	.000	.827
An increase in clinker production can be achieved by firing NG as compared to coal	126.21	91.612	-.071	.859
Coal based production Leaves behind ash requires disposal	124.16	78.012	.943	.797
Significant water is needed to remove impurities in coal based production	123.95	84.962	.948	.811
Emission of CO2, SO2, NOX, mercury compounds in coal based production is higher.	124.37	71.395	.937	.787
Coal contains minor amounts of the radioactive elements, UR & Th. When coal is burnt, the fly ash contains Ur & Th "at up to 10 times their original levels	126.93	83.583	.515	.814

Coal based captive power plants requires heavy machinery and maintenance with technical expertise	124.16	78.012	.943	.797
Coal based captive power plants requires more water to get rid of impurities.	123.95	84.962	.948	.811
The continuous volatility in fuel prices in international markets, a probable ban on the usage of petroleum coke, and the uncertainty over availability of domestic and linkage coal, continue to po...	124.21	85.176	.739	.812
Power and Fuel costs in Cement Industry account for more than 50% of the Cost of production and around 20% of Revenue	124.42	78.120	.954	.797
Elimination of coal grinding can save electric power/ton cement if Natural Gas is used	124.44	82.600	.624	.810
In addition to the potential for higher clinker production and the falling price of natural gas energy, further benefits of firing natural gas are the savings on handling costs	124.23	89.666	.245	.824
Cost of environmental damages from coal plants is higher as compare to natural gas	124.16	78.012	.943	.797

Higher Capital Cost Adjustment for Size and Time is required to shift captive power plants based on natural gas.	124.98	98.370	-.269	.869
As coal fuel contains sulfur and when it mixes with air it makes a toxic substance responsible for pollution in many lakes and rivers	124.42	78.120	.954	.797
Air pollution from coal-fired power plants is linked with asthma, cancer, heart and lung ailments, neurological problems, acid rain, global warming, and other severe environmental and public healt...	123.74	92.243	.000	.827
Lakes, rivers, streams, and drinking water supplies are all heavily impacted by coal based power plants in Rajasthan	124.44	82.600	.624	.810
Wildlife activity in the Rajasthan is changing dangerously, as conditions become hotter and drier due to climate change.	124.70	82.564	.744	.808
Coal combustion produces more greenhouse gases than the combustion of any other fossil fuel consequently affect environment badly.	124.42	78.120	.954	.797
Lack of adequate coal supply within the time frame of your cement plant is a challenge.	124.74	90.191	.113	.828

Stocking coal is always a challenge since coal mines are too distant from the captive power plants	124.28	97.243	-.533	.840
Inbound and outbound logistics and logistics planning is difficult in case of coal based captive power plants	123.95	84.962	.948	.811
Coal-fired plants emit not only carbon dioxide, There are also other toxins that have an immediate and direct impact on people's health such as Hg	123.95	84.962	.948	.811
Avoiding coal burning would save hundreds million $ a year in healthcare costs by avoiding illnesses caused by pollutants, such as asthma attacks, heart attacks and deaths linked to the coal-fired...	124.21	85.176	.739	.812
Proximity to suppliers of coal and Markets is a challenge and affects sales volume and price per unit	124.21	85.176	.739	.812
Maintaining the quality standards of coal during the supply throughout the year is a challenge	124.02	97.064	-.568	.839
Capacity utilization and increasing plant capacity both are more feasible with natural gas based captive power plants and compare to coal	124.02	97.064	-.568	.839

Group captive power plants based on coal, solar and wind are operational in large numbers in cement industry of Rajasthan state. The concept was evolve by industries to avoid the cross-subsidy Ch...	124.28	97.243	-.533	.840

3.8.2 Interpretation

The questionnaire used for survey has a total of 30 question or items based on Likert 5.0 scale parameters. The trustworthiness of frameworks was evaluated using Cronbach's alpha and aggregate average was >= 0.7, denoting that all constructs were logical and consistent.

3.9 HYPOTHESIS

S. No.	Major Hypothesis	Test Applied	Result
1	H01: Technical and Commercial respondents do not differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry. Ha1: Technical and Commercial respondents differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry.	Mann-Whitney U Test	H0 Partially accepted
2	H02: Respondents from different plant age groups do not differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry. Ha2: Respondents from different plant	Kruskal-Wallis Test	H0 Partially accepted

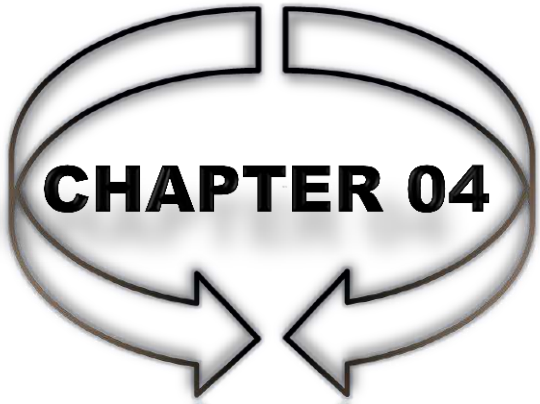
	age groups do differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry.		

3.10 LIMITATIONS OF THE STUDY

- There is relatively little actual published information, which meets particularly the study's criteria. In contrast, the existing material is conceptual and fragmentary in nature.
- This study was done only in top 10 cement plants in Rajasthan. If sufficient resource and time was available, it could be conducted in other plants throughout country in order to achieve diverse and better outcomes.
- Always in primary survey, there is a chance of biased reviews.
- Few stakeholders were considered in the sample; out of that, surveying rest of them might give different result.
- Respondents' perception is not stagnant in a particular time. In future whenever they would be survey, their perceptions might differ.
- Sampled plants have not shared Financial facts related to their operations and cost hence it was very difficult to measure financial feasibility of natural gas in cement plants.

3.11 CONCLUDING REMARKS

The research design used in this study was a vital piece of this chapter. Suitable sampling size calculations were also stipulatedand the participant characteristics. Research tools were established, and techniques as well as research methods for analysis of data were outlined, along with hypothesized relationships and other moral implications.



RESULTS AND DISCUSSION

KEY HIGHLIGHTS

- *Overview, Data Analysis and Interpretation*
- *The Analysis of the Data on Plant Age, Structure, Size and Capacity*
- *The Analysis of the Data Collected on the Technical Issues Concerning the Utilization of Coal as Fuel in Cement Power Plants*
- *The Analysis of the Data Collected on the Cost Issues Associated With the Utilization of Coal as Fuel in Cement Power Plants*
- *The Analysis of the Data Collected on Several Emerging Issues Surrounding the Utilization of Coal as Fuel in Cement Power Plants*
- *The Analysis of the Descriptive Statistics of the Study*
- *Normality Test, Reliability Test*
- *Hypothesis Testing, Mean Based Comparison*
- *Analysis on Case Based Study: Natural Gas as Clean Fuel in Comparison of Coal: Evidence From Foreign Nations*
- *Coal as Fuel in Cement Industry in India, Concluding Remarks*

4.1 OVERVIEW

A majority of the power plants in the cement industries functioning in the state of Rajasthan presently use coal as the primary fuel. It is important to note that the utilization of coal leads to several severe health-related and environmental issues. In this context, several studies have revealed that there are other types of fuel that are more cost-effective, efficient, environment friendly, and safer to use. One of the aforementioned alternative types of fuel is 'Natural Gas'. Therefore, this study is an attempt to ascertain the feasibility of the utilization of 'Natural Gas' as a fuel in the cement power plants in Rajasthan.

To conduct this study, a structured questionnaire was administered to the individuals working in various management positions in the aforementioned power plants. The aforementioned questionnaire was designed to record the responses and opinions of the respondents on the utilization of coal in cement power plants and the possibility of selecting alternative forms of fuel. In this context, the data collected during the study has shed light on the views held by the management-cadre employees of various cement factories in Rajasthan.

4.2 DATA ANALYSIS AND INTERPRETATION

This section comprises the analysis of the data collected during the course of the study by means of a structured questionnaire. Furthermore, this section is aimed at drawing relevant interpretations and inferences from the aforementioned data analysis.

The data analysis for the study has been divided into seven sections that are listed below.

- Analysis of demographic data;
- Analysis of the data on plant structure, size, and capacity;
- Analysis of the data collected on the technical issues concerning the utilization of coal as fuel;
- Analysis of the data collected on the cost issues associated with the utilization of coal as fuel;
- Analysis of the data collected on the environmental and regulatory issues surrounding the utilization of coal as fuel;

- ❖ Analysis of the data collected on the issues associated with the supply and logistics of coal;
- ❖ Analysis of the data collected on the emerging issues surrounding the utilization of coal as fuel;
- ❖ Analysis of the descriptive statistics for the study.

4.2.1 The analysis of demographic data

The questionnaire comprised questions on the gender, age, educational qualifications, and designations of the respondents in their respective workplaces. In this context, the data thus collected and organised has been analysed. The data analysis for the demographic variables of the respondents is as following.

4.2.2 Gender wise distribution of respondents

Gender wise distribution of respondents				
Gender	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Male	306	79.1	79.1	79.1
Female	81	20.9	20.9	100.0
Total	387	100.0	100.0	

According to the findings from the data analysis, it has been revealed that 79.1 percent of the respondents of the study are male whilst 20.9 percent are female. Therefore, a majority of the respondents are male.

4.2.3 Age wise distribution of respondents

Age Group				
Age	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
25-40 Years	63	16.3	16.3	16.3
40-55 Years	216	55.8	55.8	72.1
55 and Above	108	27.9	27.9	100.0
Total	387	100.0	100.0	

The findings from the data analysis have revealed that 55.8 percent of the respondents are from the 40 to 55 years age group. Furthermore, 27.9 percent of the

respondents are 55 years old or older. The remaining 16.3 percent of the respondents are the 25 to 40 years age group. Therefore, a majority of the respondents of the study are middle-aged individuals.

4.2.4 Techno- commercial education wise distribution of respondents

Education Background		Frequency	Percent	Cumulative Percent
Valid	Technical	135	34.89	34.89
	Commercial	252	65.11	100.0
	Total	387	100.0	

According to the findings from the data analysis, it has been revealed that 34.89 percent of the respondents were having technical education background with the range of graduation & Post graduations streams spanning Diploma, Diploma with Engineering, Engineering, Technology, HSE (Health Safety & Environment), Computers, Mathematics, Chemistry and Physics. Furthermore, 65.11 percent of the respondents of the study are commercially qualified like Masters of Business Administration, Chartered Accountancy, Masters of Economics, Masters of Accountancy and Masters of Arts.

4.2.5 Techno-commercial profession wise distribution of respondents

Type of respondents		Frequency	Percent	Cumulative Percent
Valid	Technical	306	79.1	79.1
	Commercial	81	20.9	100.0
	Total	387	100.0	

According to the findings from the data analysis, it has been revealed that 79.1 percent of the respondents of the study are Technical profession whilst 20.9 percent are Commercial Profession. Therefore, a majority of the respondents were Technical in cement power plants in the state of Rajasthan.

4.3 THE ANALYSIS OF THE DATA ON PLANT AGE, STRUCTURE, SIZE, AND CAPACITY

This section is aimed at assessing and analysing the structure, capacity, and size of the cement power plants that were covered under the study. In this context, the data analysis based on the aforementioned parameters is as following.

4.3.1 Plant age wise distribution of respondents

Age of plant Group				
Plant Age	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
0-2 Years	63	16.3	16.3	16.3
2-5 Years	216	55.8	55.8	72.1
5-10 year	108	27.9	27.9	100.0
Total	387	100.0	100.0	

The findings from the data analysis have revealed that 55.8 percent of the respondents are from the 2-5 years' age old plant. Furthermore, 27.9 percent of the respondents belongs to are 5-10 year years old plant. The remaining 16.3 percent of the respondents are the 0 to 2 years' age plant group. Therefore, a majority of the respondents of the study are from well-established cement power plant.

4.3.2 Size of the power plants

Size of the plant				
Plant Size	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
1400MW (2X700 MW)	90	23.3	23.3	23.3
660MW	180	46.5	46.5	69.8
Coal based captive plant	117	30.2	30.2	100.0
Total	387	100.0	100.0	

According to the findings from the data analysis, it has been revealed that 46.5 percent of the cement power plants considered under the study have a size of 660 Megawatts. In addition to this, 23.3 percent of the power plants are of the size 1,400 Megawatts (2 X 700 Megawatts) whilst 30.2 percent are 'Coal-based captive plants'. Therefore, almost half of the power plants that are a part of the study have the size of 660 Megawatts.

4.3.3 Installed capacity of the captive power plants (cpp)

S. No	Name of The cement plant	Plant Size / Installed Capacity
1.	Ambuja Cements Ltd	29.65 MTPA
2.	ACC Limited	1.6 MTPA
3.	Binani Cement Ltd	6.25 MTPA
4.	Birla Corporation Ltd	15.5 MTPA
5.	India Cements Ltd	1.5 MTPA
6.	J.K. Cement Ltd	10.5 MTPA
7.	Mangalam Cement Ltd	4.06 MTPA
8.	Shree Cement Ltd	43.4 MTPA
9.	UltraTech Cement Ltd	1.5 MTPA
10.	Wonder Cement Ltd	8 MTPA

Above table presents Installed capacity of the selected Captive power plants (CPP) in Rajasthan.

4.3.4 Type of fuel utilised in the power plants

Type of Fuel that is used in your plant				
Type of Fuel	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Coal	387	100.0	100.0	100.0

The findings from the data analysis have revealed that all the cement power plants covered under the study utilise coal as a fuel.

4.3.5 Daily fuel requirement of the power plants

Fuel Consumption per Day				
Fuel Consumption	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
18000 MT	90	23.3	23.3	23.3
22560 T	90	23.3	23.3	46.5
54720 T	90	23.3	23.3	69.8
No idea	117	30.2	30.2	100.0

Total	387	100.0	100.0	

According to the findings from the data analysis, it has been revealed that 23.3 percent of the cement power plants considered under the study have a daily fuel requirement of 18,000 Metric tonnes. Furthermore, 23.3 percent of the power plants need 22,560 tonnes of fuel every day for various operations whilst the same percentage of power plants have a daily fuel demand of 54,720 tonnes. In addition to this, the remaining 30.2 percent of the power plants have reported that they do not have a precise estimation of their daily fuel demand.

4.4 THE ANALYSIS OF THE DATA COLLECTED ON THE TECHNICAL ISSUES CONCERNING THE UTILIZATION OF COAL AS FUEL IN CEMENT POWER PLANTS

The questionnaire comprised questions on the various technical issues surrounding the utilization of coal as a fuel in cement power plants. In this context, the respondents were asked to respond to certain statements and register their agreement or disagreement on said statements. The data analysis for the responses of the respondents on the aforementioned technical issues is as following.

4.4.1 Respondents' level of agreement whether calorific value of coal is less than natural gas

The calorific values of coal is lesser than natural gas				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	189	48.8	48.8	48.8
Strongly Agree	198	51.2	51.2	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'The calorific value of coal is less than natural gas'. In this context, calorific value can be described as "the amount of heat energy present in food or fuel that is determined by the complete combustion of a specified quantity of the food or fuel at constant pressure and in normal conditions". According to the findings from the data analysis, all of the respondents of the study registered an agreement with the statement.

Therefore, all of the respondents opine that coal produces lower amounts of energy upon combustion as compared to natural gas.

4.4.2 Respondents' level of agreement whether stoichiometric air requirements of natural gas are greater than coal

The stoichiometric air requirements of natural gas are greater than coal				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Strongly Disagree	99	25.6	25.6	25.6
Disagree	99	25.6	25.6	51.2
Agree	189	48.8	48.8	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'The stoichiometric air requirements of natural gas are greater than coal'. In this context, stoichiometric air requirements is "the amount of air required for the complete combustion of fuel". According to the findings from the data analysis, **51.2 percent of the respondents of the study registered a disagreement with the statement.**

Therefore, a majority of the respondents are of the view that natural gas requires lesser quantities of air for combustion as compared to coal.

4.4.3 Respondents' level of agreement whether natural gas mixes with the air and burns more quickly as compared to coal

Natural gas mixes with the air and burns quickly as compared to coal				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Strongly Agree	387	100.0	100.0	100.0

The respondents were asked to state their opinions on the statement 'Natural gas mixes with the air and burns more quickly as compared to coal'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents opine that natural gas burns faster as compared to coal.

4.4.4 Respondents' level of agreement whether an increase in clinker production can be achieved by firing natural gas as compared to coal

An increase in clinker production can be achieved by firing NG as compared to coal				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Strongly Disagree	198	51.2	51.2	51.2
Neutral	81	20.9	20.9	72.1
Strongly Agree	108	27.9	27.9	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'An increase in clinker production can be achieved by firing natural gas as compared to coal' According to the findings from the data analysis, **51.2 percent of the respondents of the study registered a disagreement with the statement.**

Therefore, a majority of the respondents are of the view that the utilization of natural gas as a fuel in the process of cement production does not result in an increase in the quantity of clinker produced as compared to the corresponding quantity of clinker produced in coal-based production of cement.

4.4.5 Respondents' level of agreement whether coal-based production leaves behind ash that requires disposal

Coal based production Leaves behind ash requires disposal				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Neutral	81	20.9	20.9	20.9
Strongly Agree	306	79.1	79.1	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Coal-based production leaves behind ash that requires disposal'. According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents opine that coal-based production results in the generation of ash that needs to be disposed.

4.4.6 Respondents' level of agreement whether significant amount of water is needed to remove the impurities in coal-based production

Significant water is needed to remove impurities in coal based production				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	81	20.9	20.9	20.9
Strongly Agree	306	79.1	79.1	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'A significant amount of water is needed to remove the impurities in coal-based production'. According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents are of the view that coal-based production of cement requires significant quantities of water for the removal of impurities.

4.4.7 Respondents' level of agreement whether emission of co2, so2, nox, and mercury compounds in coal-based production is higher

Whether emission of CO2, SO2, NOX, and mercury compounds in coal-based production is higher				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Disagree	81	20.9	20.9	20.9
Strongly Agree	306	79.1	79.1	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'The emission of CO2, SO2, NOX, and mercury compounds in coal-based production is higher'. According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents opine that coal-based production of cement results in the emission of compounds such as CO2 and SO2 which have adverse effects on the environment.

4.4.8 Respondents' level of agreement whether coal contains minor amounts of radioactive elements, namely ur and th. When coal is burnt, the fly ash contains ur and th at up to 10 times their original levels

Whether coal contains minor amounts of radioactive elements, namely Ur and Th. When coal is burnt, the fly ash contains Ur and Th at up to 10 times their original levels				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Strongly Disagree	180	46.5	46.5	46.5
Disagree	99	25.6	25.6	72.1
Neutral	108	27.9	27.9	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Coal contains minor amounts of radioactive elements, namely Ur and Th. When coal is burnt, the fly ash contains Ur and Th at up to 10 times their original levels'. According to the findings from the data analysis, **72.1 percent of the respondents of the study registered a disagreement with the statement.**

Therefore, a majority of the respondents are of the view that the process of burning coal does not produce ash that contains Ur and Th at up to 10 times their original levels.

4.4.9 Respondents' level of agreement whether coal-based captive power plants require heavy machinery and maintenance along with technical expertise

Whether Coal based captive power plants requires heavy machinery and maintenance with technical expertise				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Neutral	81	20.9	20.9	20.9
Strongly Agree	306	79.1	79.1	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Coal-based captive power plants require heavy machinery and maintenance along with technical expertise' According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents are of the view that coal-based production of cement requires the application of heavy machinery and technical expertise.

4.4.10 Respondents' level of agreement whether coal-based captive power plants require more water to get rid of impurities

Coal based captive power plants requires more water to get rid of impurities.				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	81	20.9	20.9	20.9
Strongly Agree	306	79.1	79.1	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Coal-based captive power plants require more water to get rid of impurities'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents opine that coal-based captive power plants have a high requirement of water for the removal of impurities.

4.5 THE ANALYSIS OF THE DATA COLLECTED ON THE COST ISSUES ASSOCIATED WITH THE UTILIZATION OF COAL AS FUEL IN CEMENT POWER PLANTS

The questionnaire comprised questions on the various cost issues associated with the utilization of coal as a fuel in cement power plants. In this context, the respondents were asked to respond to certain statements and register their agreement or disagreement on said statements. The data analysis for the responses of the respondents on the aforementioned cost issues is as following.

4.5.1 Respondents' level of agreement whether continuous volatility in fuel prices in international markets, a probable ban on the usage of petroleum coke, and the uncertainty over the availability of domestic and linkage coal continue to pose challenges for the cement industry

Whether continuous volatility in fuel prices in international markets, a probable ban on the usage of petroleum coke, and the uncertainty over the availability of domestic and linkage coal continue to pose challenges for the cement industry				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	180	46.5	46.5	46.5
Strongly Agree	207	53.5	53.5	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'The continuous volatility in fuel prices in international markets, a probable ban on the usage of petroleum coke, and the uncertainty over the availability of domestic and linkage coal continue to pose challenges for the cement industry'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents opine that the fluctuations in the availability and pricing of coal in the international as well as domestic markets lead to continuous challenges for the cement industry.

4.5.2 Respondents' level of agreement whether power and fuel costs in the cement industry account for more than 50% of the total cost of production and around 20% of the total revenue

Whether power and fuel costs in the cement industry account for more than 50% of the total cost of production and around 20% of the total revenue				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Neutral	81	20.9	20.9	20.9
Agree	99	25.6	25.6	46.5
Strongly Agree	207	53.5	53.5	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'The power and fuel costs in the cement industry account for more than 50% of the total cost of production and around 20% of the total revenue'. According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents are of the view that the costs associated with power and fuel constitute a significant percentage of the total cost of production incurred in coal-based production of cement. Furthermore, the aforementioned respondents also opine that power and fuel costs consume a fifth of the revenue earned from the production and sale of cement.

4.5.3 Respondents' level of agreement whether elimination of coal grinding can save electric power/ton cement if natural gas is used

Whether elimination of coal grinding can save electric power/ton cement if natural gas is used				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Neutral	81	20.9	20.9	20.9
Agree	108	27.9	27.9	48.8
Strongly Agree	198	51.2	51.2	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'The elimination of coal grinding can save electric power/ton cement if natural gas is used'. According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents are of the view that the elimination of the process of grinding of coal can lead to significant savings in terms of electrical power per ton of cement produced if natural gas is used instead.

4.5.4 Respondents' level of agreement whether in addition to the potential for higher clinker production and the falling price of natural gas energy, further benefits of firing natural gas are the savings on handling costs

Whether in addition to the potential for higher clinker production and the falling price of natural gas energy, further benefits of firing natural gas are the savings on handling costs				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	189	48.8	48.8	48.8
Strongly Agree	198	51.2	51.2	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'In addition to the potential for higher clinker production and the falling price of natural gas energy, further benefits of firing natural gas are the savings on handling costs'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents opine that the utilization of natural gas as fuel in the production of cement instead of coal can lead to savings in terms of lower fuel cost and lower handling costs.

4.5.5 Respondents' level of agreement whether cost of environmental damages from coal plants is higher as compared to natural gas-based plants

Whether cost of environmental damages from coal plants is higher as compared to natural gas-based plants				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Neutral	81	20.9	20.9	20.9
Strongly Agree	306	79.1	79.1	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'The cost of environmental damages from coal plants is higher as compared to natural gas-

based plants'. According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents are opine that coal-based cement power plants cause significantly greater damage to the environment as compared to the power plants that utilise natural gas as fuel.

4.5.6 Respondents' level of agreement whether higher capital cost adjustment for size and time is required to shift captive power plants based on natural gas

Whether Higher Capital Cost Adjustment for size and time is required to shift captive power plants based on natural gas				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Strongly Disagree	99	25.6	25.6	25.6
Agree	81	20.9	20.9	46.5
Strongly Agree	207	53.5	53.5	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Higher Capital Cost Adjustment for size and time is required to shift captive power plants based on natural gas.' According to the findings from the data analysis, **74.4 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents are of the view that significant investments in terms of capital cost are required to shift captive power plants to natural gas-based power plants.

4.6 THE ANALYSIS OF THE DATA COLLECTED ON THE ENVIRONMENTAL AND REGULATORY ISSUES SURROUNDING THE UTILIZATION OF COAL AS FUEL IN CEMENT POWER PLANTS

The questionnaire comprised questions on the various environmental and regulatory issues associated with the utilization of coal as a fuel in cement power plants. In this context, the respondents were asked to respond to certain statements and register their agreement or disagreement on said statements. The data analysis for the responses of the respondents on the aforementioned environmental and regulatory issues is as following.

4.6.1 Respondents' level of agreement whether coal fuel contains sulphur and when it mixes with air, it makes a toxic substance that is responsible for causing pollution in many lakes and rivers

Whether coal fuel contains sulphur and when it mixes with air, it makes a toxic substance that is responsible for causing pollution in many lakes and rivers				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Neutral	81	20.9	20.9	20.9
Agree	99	25.6	25.6	46.5
Strongly Agree	207	53.5	53.5	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Coal fuel contains sulphur and when it mixes with air, it makes a toxic substance that is responsible for causing pollution in many lakes and rivers'. According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents opine that coal-based production of cement leads to the creation of a toxic sulphur-based compound that causes widespread water pollution.

4.6.2 Respondents' level of agreement whether air pollution from coal-based power plants is linked with asthma, cancer, heart and lung ailments, neurological problems, acid rain, global warming, and other severe environmental and public health hazards

Whether air pollution from coal-based power plants is linked with asthma, cancer, heart and lung ailments, neurological problems, acid rain, global warming, and other severe environmental and public health hazards				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Strongly Agree	387	100.0	100.0	100.0

The respondents were asked to state their opinions on the statement 'The air pollution from coal-based power plants is linked with asthma, cancer, heart and lung ailments, neurological problems, acid rain, global warming, and other severe

environmental and public health hazards'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents are of the view that the utilization of coal as fuel in the production of cement causes several health hazards and has a adverse impact on the environment.

4.6.3 Respondents' level of agreement whether lakes, rivers, streams, and drinking water supplies are all heavily impacted by coal-based power plants in Rajasthan

Whether lakes, rivers, streams, and drinking water supplies are all heavily impacted by coal-based power plants in Rajasthan				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Neutral	81	20.9	20.9	20.9
Agree	108	27.9	27.9	48.8
Strongly Agree	198	51.2	51.2	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Lakes, rivers, streams, and drinking water supplies are all heavily impacted by coal-based power plants in Rajasthan'. According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents opine that coal-based production of cement pollutes water bodies, including lakes, rivers, and streams. Furthermore, the aforementioned respondents are of the view that the use of coal as fuel in cement production causes contamination in the supply of drinking water in the state of Rajasthan.

4.6.4 Respondents' level of agreement whether wildlife activity in Rajasthan is changing dangerously as conditions become hotter and drier due to climate change

Whether wildlife activity in Rajasthan is changing dangerously as conditions become hotter and drier due to climate change				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Neutral	81	20.9	20.9	20.9
Agree	207	53.5	53.5	74.4
Strongly Agree	99	25.6	25.6	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Wildlife activity in Rajasthan is changing dangerously as conditions become hotter and drier due to climate change'. According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents are of the view that the patterns of activity displayed by the wildlife in Rajasthan are changing quickly and continuously owing to climate change related factors.

4.6.5 Respondents' level of agreement whether coal combustion produces more greenhouse gases than the combustion of any other fossil fuel, consequently adversely affecting the environment

Whether coal combustion produces more greenhouse gases than the combustion of any other fossil fuel, consequently adversely affecting the environment				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Neutral	81	20.9	20.9	20.9
Agree	99	25.6	25.6	46.5
Strongly Agree	207	53.5	53.5	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Coal combustion produces more greenhouse gases than the combustion of any other fossil fuel, consequently adversely affecting the environment'. According to the findings from the data analysis, **79.1 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents opine that the burning of coal results in the production of higher quantities of greenhouses gases as compared to other fossil fuels, thereby causing an adverse impact on the environment.

4.7 THE ANALYSIS OF THE DATA COLLECTED ON THE SUPPLY AND LOGISTICS ISSUES SURROUNDING THE UTILIZATION OF COAL AS FUEL IN CEMENT POWER PLANTS

The questionnaire comprised questions on the various supply and logistics issues associated with the utilization of coal as a fuel in cement power plants. In this context, the respondents were asked to respond to certain statements and register their agreement or disagreement on said statements. The data analysis for the responses of the respondents on the aforementioned supply and logistics issues is as following.

4.7.1 Respondents' level of agreement whether lack of adequate supply of coal within the time frame of your cement plant is a challenge

Whether lack of adequate supply of coal within the time frame of your cement plant is a challenge				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Neutral	99	25.6	25.6	25.6
Agree	189	48.8	48.8	74.4
Strongly Agree	99	25.6	25.6	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'The lack of adequate supply of coal within the time frame of your cement plant is a challenge'. According to the findings from the data analysis, **74.4 percent of the respondents of the study registered an agreement with the statement.**

Therefore, a majority of the respondents opine that owing to the lack of adequate and timely supply of coal, the operations and the efficiency of their cement power plants are adversely affected.

4.7.2 Respondents' level of agreement whether stocking coal is always a challenge since coal mines are too distant from the captive power plants

Whether stocking coal is always a challenge since coal mines are too distant from the captive power plants				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	207	53.5	53.5	53.5
Strongly Agree	180	46.5	46.5	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Stocking coal is always a challenge since coal mines are too distant from the captive power plants'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents are of the view that the long distances between the coal mines and the captive power plants lead to bottlenecks in the movement and stocking of coal, thereby hampering the efficiency of the operations of the power plants.

4.7.3 Respondents' level of agreement whether inbound and outbound logistics and logistics planning is difficult in case of coal-based captive power plants

Whether inbound and outbound logistics and logistics planning is difficult in case of coal-based captive power plants				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	81	20.9	20.9	20.9
Strongly Agree	306	79.1	79.1	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Inbound and outbound logistics and logistics planning is difficult in case of coal-based captive power plants'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents opine that it is difficult to manage the planning and execution of inbound and outbound logistics in the case of coal-based captive power plants.

4.8 THE ANALYSIS OF THE DATA COLLECTED ON SEVERAL EMERGING ISSUES SURROUNDING THE UTILIZATION OF COAL AS FUEL IN CEMENT POWER PLANTS

The questionnaire comprised questions on various emerging issues associated with the utilization of coal as a fuel in cement power plants. In this context, the respondents were asked to respond to certain statements and register their agreement or disagreement on said statements. The data analysis for the responses of the respondents on the aforementioned emerging issues is as following.

4.8.1 Respondents' level of agreement whether coal-based plants emit not only carbon dioxide but also several other toxins that have an immediate and direct impact on people's health, including Hg

Whether coal-based plants emit not only carbon dioxide but also several other toxins that have an immediate and direct impact on people's health, including Hg				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	81	20.9	20.9	20.9
Strongly Agree	306	79.1	79.1	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Coal-based plants emit not only carbon dioxide but also several other toxins that have an immediate and direct impact on people's health, including Hg'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents are of the view that coal-based power plants lead to the production of several harmful substances, including Carbon dioxide and Mercury that have an adverse impact on the health of the people working in those plants.

4.8.2 Respondents' level of agreement whether avoiding burning coal would save hundreds of million dollars every year in healthcare costs by avoiding illnesses caused by pollutants, including asthma attacks, heart attacks, and deaths linked to the coal-based power plants' emissions

Whether avoiding burning coal would save hundreds of million dollars every year in healthcare costs by avoiding illnesses caused by pollutants, including asthma attacks, heart attacks, and deaths linked to the coal-based power plants' emissions				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	180	46.5	46.5	46.5
Strongly Agree	207	53.5	53.5	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Avoiding burning coal would save hundreds of million dollars every year in healthcare costs by avoiding illnesses caused by pollutants, including asthma attacks, heart attacks, and deaths linked to the coal-based power plants' emissions'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents opine that avoiding the process of burning coal can lead to substantial savings in terms of healthcare costs. Since the emission of harmful pollutants by coal-based power plants leads to diseases such as asthma and cardiac issues, avoiding the burning of coal can lead to a reduction in the occurrence of said diseases.

4.8.3 Respondents' level of agreement whether proximity to suppliers of coal and markets is a challenge and affects sales volume and price per unit

Whether proximity to suppliers of coal and markets is a challenge and affects sales volume and price per unit				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	180	46.5	46.5	46.5
Strongly Agree	207	53.5	53.5	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'the proximity to suppliers of coal and markets is a challenge and affects sales volume and price per unit'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents opine that the lack of proximity of coal-based power plants with the suppliers of coal and relevant markets adversely affects the total volume of sales and the per unit cost of coal.

4.8.4 Respondents' level of agreement whether maintaining the quality standards of coal during the supply throughout the year is a challenge

Whether maintaining the quality standards of coal during the supply throughout the year is a challenge				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	108	27.9	27.9	27.9
Strongly Agree	279	72.1	72.1	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Maintaining the quality standards of coal during the supply throughout the year is a challenge'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents are of the view that it is challenging to maintain the quality standards of coal over the course of its supply throughout the year.

4.8.5 Respondents' level of agreement whether capacity utilization and increasing plant capacity both are more feasible for natural gas-based power plants as compared to coal-based power plants

Whether capacity utilization and increasing plant capacity both are more feasible for natural gas-based power plants as compared to coal-based power plants				
	Frequency	**Percent**	**Valid Percent**	**Cumulative Percent**
Agree	108	27.9	27.9	27.9
Strongly Agree	279	72.1	72.1	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Capacity utilization and increasing plant capacity both are more feasible for natural gas-based power plants as compared to coal-based power plants'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents opine that there is a higher feasibility for the achievement of full capacity utilization and capacity enhancement in natural gas-based power plants as compared to coal-based power plants.

4.8.6 Respondents' level of agreement whether group captive power plants based on coal, solar, and wind energy are operational in large numbers in the cement industry of Rajasthan. The concept was evolved by the industry to avoid the cross-subsidy charges levied on the inter-state sale of electricity and is seen as a threat to state discoms

Whether group captive power plants based on coal, solar, and wind energy are operational in large numbers in the cement industry of Rajasthan. The concept was evolved by the industry to avoid the cross-subsidy charges levied on the inter-state sale of electricity and is seen as a threat to state discoms				
	Frequency	**Per cent**	**Valid Per cent**	**Cumulative Per cent**
Agree	207	53.5	53.5	53.5
Strongly Agree	180	46.5	46.5	100.0
Total	387	100.0	100.0	

The respondents were asked to state their opinions on the statement 'Group captive power plants based on coal, solar, and wind energy are operational in large numbers in the cement industry of Rajasthan. The concept was evolved by the industry to avoid the cross-subsidy charges levied on the inter-state sale of electricity and is seen as a threat to state discoms'. According to the findings from the data analysis, **all of the respondents of the study registered an agreement with the statement.**

Therefore, all of the respondents are of the view that the concept of cement power plants that utilise various forms of energy as fuel, including coal, solar, and wind energy, is useful in saving the cost associated with the cross-subsidy charges levied by different states on the inter-state sale of electricity. Furthermore, the aforementioned respondents opine that the application of such power plants is a threat to electricity distribution companies because it affects their total revenue.

4.9 THE ANALYSIS OF THE DESCRIPTIVE STATISTICS OF THE STUDY

This section is aimed at discussing the various descriptive statistics that have been calculated on the basis of the data analysis of the study. In this context, the mean values of the responses of the respondents on the various statements in the questionnaire has been computed. It is important to note that the mean values are on a scale of 0 to 5 with values higher than 3 indicating the respondents' agreement with a statement and values lower than 3 representing the respondents' disagreement with a statement. The major inferences drawn from the analysis of the aforementioned mean values are listed below.

Descriptive Statistics		
	Mean	**Std. Deviation**
Technical issue	3.9698	.46140
Cost Issues	4.3372	.45310
Environmental Regulatory Issues	4.4000	.55979
Supply/logistic issues	4.4186	.36769
Emerging Issues	4.6279	.21844

The statement 'Natural gas mixes with the air and burns more quickly as compared to coal' has the highest mean value, that is, 5, amongst the various statements in the section of technical issues to which the respondents were asked to respond. In this context, this mean value is the maximum possible mean value on the scale of 0 to 5 and indicates that all of the respondents either agreed or strongly agreed with the statement.

- On the other hand, the statement 'Coal contains minor amounts of radioactive elements, namely Ur and Th. When coal is burnt, the fly ash contains Ur and Th at up to 10 times their original levels' has the lowest mean value, that is, 1.81, amongst the various statements in the section of technical issues to which the respondents were asked to respond. In this context, this mean value indicates that a majority of the respondents either disagreed or strongly disagreed with the statement.

- The statement 'The cost of the environmental damages from coal-based power plants is higher as compared to natural gas-based power plants' has the highest mean value, that is, 4.58, amongst the various statements in the section of cost issues to which the respondents were asked to respond. In this context, this mean value indicates that a majority of the respondents either agreed or strongly agreed with the statement.

- On the other hand, the statement 'Higher Capital Cost Adjustment for size and time is required to shift captive power plants based on natural gas' has the lowest mean value, that is, 3.77, amongst the various statements in the section of cost issues to which the respondents were asked to respond. In this context, this mean value indicates that a majority of the respondents either agreed or strongly agreed with the statement.

- The statement 'The air pollution from coal-based power plants is linked with asthma, cancer, heart and lung ailments, neurological problems, acid rain, global warming, and other severe health hazards' has the highest mean value, that is, 5, amongst the various statements in the section of environmental and regulatory issues to which the respondents were asked to respond. In this context, mean value is the maximum possible mean value on the scale of 0 to 5 and indicates that all of the respondents either agreed or strongly agreed with the statement.

- On the other hand, the statement 'Wildlife activity in the Rajasthan is changing dangerously as conditions become hotter and drier due to climate change.' has the lowest mean value, that is, 4.05, amongst the various statements in the section of environmental and regulatory issues to which the respondents were asked to respond. In this context, this mean value indicates that a majority of the respondents either agreed or strongly agreed with the statement.

- The statement 'The inbound and outbound logistics and logistics planning is difficult in case of coal based captive power plants' has the highest mean value, that is, 4.79, amongst the various statements in the section of supply and logistics issues to which the respondents were asked to respond. In this context, this mean value indicates that a majority of the respondents either agreed or strongly agreed with the statement.

- On the other hand, the statement 'The lack of adequate coal supply within the time frame of your cement plant is a challenge.' has the lowest mean value, that is, 4, amongst the various statements in the section of supply and logistics issues to which the respondents were asked to respond. In this context, this mean value indicates that a majority of the respondents either agreed or strongly agreed with the statement.

- The statement 'Coal-based plants emit not only carbon dioxide but also several other toxins that have an immediate and direct impact on people's health, including Hg' has the highest mean values, that is, 4.79, amongst the various statements in the section of emerging issues to which the respondents were asked to respond. In this context, this mean value indicates that a majority of the respondents either agreed or strongly agreed with the statement.

- On the other hand, the statement 'Group captive power plants based on coal, solar, and wind energy are operational in large numbers in the cement industry of Rajasthan. The concept was evolved by the industry to avoid the cross-subsidy charges levied on the inter-state sale of electricity and is seen as a threat to state discoms' has the lowest mean value, that is, 4.47, amongst the various statements in the section of emerging issues to which the respondents were asked to respond. In this context, this mean value indicates that a majority of the respondents either agreed or strongly agreed with the statement.

4.10 NORMALITY TEST

The One-Sample Kolmogorov-Smirnov Test compares a variable's observed cumulative distribution function to a theoretical distribution that can be normal, uniform, Poisson, or exponential. The largest difference (in absolute value) between the observed and theoretical cumulative distribution functions is used to calculate the Kolmogorov-Smirnov Z. This test of fitness is called a goodness-of-fit test.

In the below table "one-sample Kolmogorov-Smirnov test" is used to examine whether a sample comes from a precise distribution i.e. whether a sample comes from a population that is normally distributed. Here null hypothesis is rejected since $p < 0.05$ means variable do not follow a normal distribution in our population.

One-Sample Kolmogorov-Smirnov Test						
		Technical issue	**Cost Issues**	**Environmental Regulatory Issues**	**Supply_ logistic_Issues**	**Emerging Issues**
N		387	387	387	387	387
Normal Parameters[a,b]	Mean	3.9698	4.3372	4.4000	4.4186	4.6279
	Std. Deviation	.46140	.45310	.55979	.36769	.21844
Most Extreme Differences	Absolute	.195	.301	.291	.336	.465
	Positive	.195	.234	.172	.336	.465
	Negative	-.193	-.301	-.291	-.199	-.279
Kolmogorov-Smirnov Z		3.832	5.927	5.719	6.608	9.149
Asymp. Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000
a. Test distribution is Normal.						
b. Calculated from data.						

4.11 RELIABILITY TEST

Cronbach's Alpha is designed as a measure of internal consistency of items in the questionnaire. It varies between zero and one. The closer alpha is to one, the greater the internal consistency of the items in the questionnaire. Total number of questions or items in the questionnaire is 30 including LIKERT scale variables. Hence "N" of items in the below Cronbach's Alpha test is 30.

Reliability Statistics	
Cronbach's Alpha	**N of Items**
.826	30

Item-Total Statistics				
	Scale Mean if Item Deleted	**Scale Variance if Item Deleted**	**Corrected Item-Total Correlation**	**Cronbach's Alpha if Item Deleted**
The calorific values of coal is lesser than natural gas	124.23	89.666	.245	.824
The stoichiometric air requirements of natural gas are greater than coal	126.02	102.287	-.446	.864
Natural gas mixes with the air and burns quickly as compared to coal	123.74	92.243	0.000	.827
An increase in clinker production can be achieved by firing NG as compared to coal	126.21	91.612	-.071	.859
Coal based production Leaves behind ash requires disposal	124.16	78.012	.943	.797
Significant water is needed to remove impurities in coal based production	123.95	84.962	.948	.811

Emission of CO2, SO2, NOX, mercury compounds in coal based production is higher.	124.37	71.395	.937	.787
Coal contains minor amounts of the radioactive elements, UR & Th. When coal is burnt, the fly ash contains Ur & Th "at up to 10 times their original levels	126.93	83.583	.515	.814
Coal based captive power plants requires heavy machinery and maintenance with technical expertise	124.16	78.012	.943	.797
Coal based captive power plants requires more water to get rid of impurities.	123.95	84.962	.948	.811
The continuous volatility in fuel prices in international markets, a probable ban on the usage of petroleum coke, and the uncertainty over availability of domestic and linkage coal, continue to po...	124.21	85.176	.739	.812
Power and Fuel costs in Cement Industry account for more than 50% of the Cost of production and around 20% of Revenue	124.42	78.120	.954	.797
Elimination of coal grinding can save electric power/ton cement if Natural Gas is used	124.44	82.600	.624	.810
In addition to the potential for higher clinker production and the falling price of natural gas energy, further benefits of firing	124.23	89.666	.245	.824

natural gas are the savings on handling costs				
Cost of environmental damages from coal plants is higher as compare to natural gas	124.16	78.012	.943	.797
Higher Capital Cost Adjustment for Size and Time is required to shift captive power plants based on natural gas.	124.98	98.370	-.269	.869
As coal fuel contains sulfur and when it mixes with air it makes a toxic substance responsible for pollution in many lakes and rivers	124.42	78.120	.954	.797
Air pollution from coal-fired power plants is linked with asthma, cancer, heart and lung ailments, neurological problems, acid rain, global warming, and other severe environmental and public healt...	123.74	92.243	0.000	.827
Lakes, rivers, streams, and drinking water supplies are all heavily impacted by coal based power plants in Rajasthan	124.44	82.600	.624	.810
Wildlife activity in the Rajasthan is changing dangerously, as conditions become hotter and drier due to climate change.	124.70	82.564	.744	.808
Coal combustion produces more greenhouse gases than the combustion of any other fossil fuel consequently affect	124.42	78.120	.954	.797

environment badly.				
Lack of adequate coal supply within the time frame of your cement plant is a challenge.	124.74	90.191	.113	.828
Stocking coal is always a challenge since coal mines are too distant from the captive power plants	124.28	97.243	-.533	.840
Inbound and outbound logistics and logistics planning is difficult in case of coal based captive power plants	123.95	84.962	.948	.811
Coal-fired plants emit not only carbon dioxide, There are also other toxins that have an immediate and direct impact on people's health such as Hg	123.95	84.962	.948	.811
Avoiding coal burning would save hundreds million $ a year in healthcare costs by avoiding illnesses caused by pollutants, such as asthma attacks, heart attacks and deaths linked to the coal-fired...	124.21	85.176	.739	.812
Proximity to suppliers of coal and Markets is a challenge and affects sales volume and price per unit	124.21	85.176	.739	.812
Maintaining the quality standards of coal during the supply throughout the year is a challenge	124.02	97.064	-.568	.839

Capacity utilization and increasing plant capacity both are more feasible with natural gas based captive power plants and compare to coal	124.02	97.064	-.568	.839
Group captive power plants based on coal, solar and wind are operational in large numbers in cement industry of Rajasthan state. The concept was evolved by industries to avoid the cross-subsidy ch...	124.28	97.243	-.533	.840

Cronbach's alpha test was performed to check the reliability of questions or items. The above tables display several results obtained. The Cronbach's alpha test was performed and it resulted in an overall score of 0.826 indicating internal consistency of the items.

4.12 HYPOTHESIS TESTING

H01: Technical and commercial respondents do not differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry.

Ha1: Technical and commercial respondents differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry.

Ranks				
	Technical/Commercial Professionals	**No.**	**Mean Rank**	**Sum of Ranks**
Technical issue	Technical	306	186.32	57015.00
	Commercial	81	223.00	18063.00
	Total	387		
Cost Issues	Technical	306	188.97	57825.00
	Commercial	81	213.00	17253.00

	Total	387		
Environmental Regulatory Issues	Technical	306	197.71	60498.00
	Commercial	81	180.00	14580.00
	Total	387		
Supply_logistic_ Issues	Technical	306	198.24	60660.00
	Commercial	81	178.00	14418.00
	Total	387		
Emerging Issues	Technical	306	201.41	61632.00
	Commercial	81	166.00	13446.00
	Total	387		

Test Statistics [a]				
	Mann-Whitney U	**Wilcoxon W**	**Z**	**Asymp. Sig. (2-tailed)**
Technical issue	10044.000	57015.000	-2.713	.007
Cost Issues	10854.000	57825.000	-1.897	.058
Environmental Regulatory Issues	11259.000	14580.000	-1.310	.190
Supply_logistic_Issues	11097.000	14418.000	-1.570	.116
Emerging Issues	10125.000	13446.000	-3.352	.001
a. Grouping Variable: Techno commercial Profession				

Since 'p' value was found more than 0.05 for "Cost Issues", "Environmental Regulatory Issues" and "Supply / logistic issues" therefore null hypothesis remains accepted. Hence it can be stated here that male and female respondents do not differ significantly in explaining "Cost Issues", "Environmental Regulatory Issues" and "Supply / logistic issues" for usage of coal as a fuel in captive power plant in cement industry. On the other hand 'p' value in the case of "Technical issues" and "Emerging Issues" was less than 0.05 for that reason Ha is accepted and significant difference in the opinion of Technical and commercial respondents exists here.

H02: Respondents from different plant age groups do not differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry.

Ha2: Respondents from different plant age groups differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry.

Ranks			
	Age of plant Group	**No.**	**Mean Rank**
Technical issue	0-2 Years	63	148.36
	2-5 Years	216	191.75
	5-10 year	108	225.13
	Total	387	
Cost Issues	0-2 Years	63	149.00
	2-5 Years	216	195.13
	5-10 year	108	218.00
	Total	387	
Environmental Regulatory Issues	0-2 Years	63	208.79
	2-5 Years	216	189.88
	5-10 year	108	193.63
	Total	387	
Supply_logistic_Issues	0-2 Years	63	235.14
	2-5 Years	216	188.00
	5-10 year	108	182.00
	Total	387	
Emerging Issues	0-2 Years	63	227.43
	2-5 Years	216	192.88
	5-10 year	108	176.75
	Total	387	

Test Statistics[a,b]			
	Chi-Square	**df**	**Asymp. Sig.**
Technical issue	20.241	2	.000
Cost Issues	18.499	2	.000
Environmental Regulatory Issues	1.492	2	.474
Supply_logistic_Issues	12.219	2	.002
Emerging Issues	14.386	2	.001
a. Kruskal Wallis Test			
b. Grouping Variable: Age of plant Group			

Since 'p' value was found more than 0.05 for "Environmental Regulatory Issues", therefore null hypothesis remains accepted. Hence it can be stated here that respondents from different age groups do not differ significantly in explaining "Environmental Regulatory Issues" for usage of coal as a fuel in captive power plant in cement industry. On the other hand 'p' value in the case of "Technical issues", "Cost Issues", "Supply / logistic issues" and "Emerging Issues" was less than 0.05 for that reason, Ha is accepted and significant difference in the opinion of respondents from different plant age groups exists here.

4.13 MEAN BASED COMPARISON

4.13.1 Mean Based Comparison for various issues related to uses of coal as a fuel in captive power plant in cement industry on the basis of plant size

Following is the mean based comparison for various issues related to uses of coal as a fuel in captive power plant in cement industry on the basis of plant size.

Technical issue, Cost Issues, Environmental Regulatory Issues, Supply / logistic issues, Emerging Issues * Size of the plant						
Size of the plant		**Technical issue**	**Cost Issues**	**Environmental Regulatory Issues**	**Supply/ logistic issues**	**Emerging Issues**
1400MW (2X700 MW)	Mean	4.2200	4.6333	4.5400	4.2333	4.5500
	Std. Deviation	.31736	.10056	.18101	.30168	.15084

660MW	Mean	3.6500	4.0333	4.3100	4.6500	4.7500
	Std. Deviation	.33485	.44721	.75968	.35807	.25070
Call based captive plant	Mean	4.2692	4.5769	4.4308	4.2051	4.5000
	Std. Deviation	.40053	.31222	.31362	.16287	0.00000
Total	Mean	3.9698	4.3372	4.4000	4.4186	4.6279
	Std. Deviation	.46140	.45310	.55979	.36769	.21844

Respondents from "Call based captive plant" were found more agreed with "Technical issues" (Mean value, 4.2692) in using coal as a fuel in captive power plant in cement industry. With mean value of 4.63, respondents from plant with size "1400MW (2X700 MW)" were much agreed as compared to other size plant's respondents as far as "Cost Issues" are concerned. Agreement with "Environmental Regulatory Issues" was found much higher in the respondents from plant with size of 1400MW (2X700 MW). For "Supply / logistic issues" and "Emerging Issues" in using coal as a fuel in captive power plant in cement industry, respondents from 660 MW size of plant found more agreed as compared to others with mean value of 4.65 and 4.75 respectively.

4.13.2 Mean Based Comparison for various issues related to uses of coal as a fuel in captive power plant in cement industry on the basis of Installed capacity of the plant

Following is the mean based comparison for various issues related to uses of coal as a fuel in captive power plant in cement industry on the basis of Installed capacity of the plant.

Technical issue Cost Issues Environmental Regulatory Issues Supply / logistic issues Emerging Issues * Installed capacity of the plant						
Installed capacity of the plant		**Technical issue**	**Cost Issues**	**Environmental Regulatory Issues**	**Supply / logistic issues**	**Emerging Issues**
1320MW	Mean	3.5700	3.9500	4.1400	4.5667	4.7000

	Std. Deviation	.27741	.46235	.76346	.36872	.24632
1400MW (2X700 MW	Mean	4.2200	4.6333	4.5400	4.2333	4.5500
	Std. Deviation	.31736	.10056	.18101	.30168	.15084
3960MW	Mean	3.7300	4.1167	4.4800	4.7333	4.8000
	Std. Deviation	.36825	.41766	.72067	.32843	.24632
4×500 TPH boilers	Mean	4.2692	4.5769	4.4308	4.2051	4.5000
	Std. Deviation	.40053	.31222	.31362	.16287	0.00000
Total	Mean	3.9698	4.3372	4.4000	4.4186	4.6279
	Std. Deviation	.46140	.45310	.55979	.36769	.21844

Respondents from "4×500 TPH boilers installed capacity" were found more agreed with "Technical issues" (Mean value, 4.26) in using coal as a fuel in captive power plant in cement industry. With mean value of 4.63 and 4.54 respectively, respondents from plant with installed capacity "1400MW (2X700 MW)" were much agreed as compared to other size plant's respondents as far as "Cost Issues" and "Environmental Regulatory Issues" are concerned. For "Supply / logistic issues" and "Emerging Issues" in using coal as a fuel in captive power plant in cement industry, respondents from 3960 MW installed capacity of plant found more agreed as compared to others with mean value of 4.73 and 4.80 respectively.

4.13.3 Mean Based Comparison for various issues related to uses of coal as a fuel in captive power plant in cement industry on the basis of Capital power plant Age

Following is the mean based comparison for various issues related to uses of coal as a fuel in captive power plant in cement industry on the basis of Plant Age.

Technical issue Cost Issues Environmental Regulatory Issues Supply / logistic issues Emerging Issues * Capital power plant Age						
Capital power plant Age		**Technical issue**	**Cost Issues**	**Environmental Regulatory Issues**	**Supply / logistic issues**	**Emerging Issues**
0-2	Mean	3.5700	3.9500	4.1400	4.5667	4.7000
	Std. Deviation	.27741	.46235	.76346	.36872	.24632
3-5	Mean	4.2692	4.5769	4.4308	4.2051	4.5000
	Std. Deviation	.40053	.31222	.31362	.16287	0.00000
5-10	Mean	3.9750	4.3750	4.5100	4.4833	4.6750
	Std. Deviation	.42174	.39858	.52481	.40216	.23915
Total	Mean	3.9698	4.3372	4.4000	4.4186	4.6279
	Std. Deviation	.46140	.45310	.55979	.36769	.21844

Respondents from Plants with 3-5 years of age were found more agreed with "Technical issues (Mean value, 4.2692)" and "Cost Issues (Mean value, 4.5769)" in using coal as a fuel in captive power plant in cement industry. Agreement with "Environmental Regulatory Issues" was found much higher in the respondents from plant with 5-10 years of age. For "Supply / logistic issues" and "Emerging Issues" in using coal as a fuel in captive power plant in cement industry, respondents from plant with 0-2 years of age found more agreed as compared to others with mean value of 4.56 and 4.70 respectively.

4.14 ANALYSIS ON CASE BASED STUDY: NATURAL GAS AS CLEAN FUEL IN COMPARISON OF COAL: EVIDENCE FROM FOREIGN NATIONS

4.14.1 Overview

The cement industry is a high-energy sector. The substitution of certain conventional fuels with alternative fuels has both economic and ecological advantages. The cement industry, from the technological and environmental point of

view, is particularly suited for the use of such fuels. In many cement factories worldwide, alternative fuels are employed. Natural Gas as Alternative fuel is already being used by many cement factories in other countries. The manufacturing of cement is highly energized. For manufacture of 1 tonne of cement the average demand for energy is approximately GJ 3.3 (Feng L, 1995), equivalent to 120 kg of carbon and a calorific value of 27.5 MJ per kilogramme. Many Researchers cited energy cost as 30–40% of the overall cost of cement manufacturing in research publications. Another fact is that cement sector energy use is around 2% or almost 5% of the world primary energy consumption [WEC, 1995]. At present in an Indian cement plants, coal and coke are the main fuels for the industry. Recently, the usage of waste fuels, especially tyre derived fuels, has increased slightly (TDF). There is a substantial growth in the number of TDF facilities globally (www.energyjustice.net).

This section examines in depth certain foreign countries' practices with respect to alternative fuels, in particular natural gas utilized in cement manufacturing. It focuses on the type of alternative combustibles utilized, their environmental and economic benefits, their influence on production and quality of concrete, the obstacles of transitioning between conventional and alternative fuels.

This chapter is aimed at providing an empirical assessment of alternative fuels, particularly natural gas. It will be an important sources of information for cement producers who wish to use natural gas in India and Rajasthan as alternative fuel.

4.14.2 Evidence from north america

- **Background of North America cement industry**

The recent trend in North America has depicted a wide adoption of renewable alternatives plant mechanism for meeting the industrial needs of energy consumption. Particularly, the Natural gas - fired plants have outreached the phenomenal significance to the energy consuming industries such as paper, cement, tire etc. as the best short-term energy replacement of coal. The incessant declining prices of gas and excessive carbon emission from coal fire, along with the strict environmental regulatory restrictions led the cement manufactures, switching to an entire new approach for production process. Studies reveal that during past years' natural gas prices have seen a major decline over coal due to the advancement of Shale gas techniques. As Shale gas reflect a likewise features of a natural gas. Moreover, the coal prices depict the double of the natural gas prices nearly $US 0.02 kilowatt/hour, leading to additional labor and housekeeping expenses. therefore,

turning from conventional to non- conventional energy sources were a convenient choice for the cement industry.

However, many natural gas plants are still far beyond the reach of many cement manufacturers, causing higher plantation cost and many safety hazards such as flame distinction, flame flash back, automatic flame valve shut off, and extinction of natural gas. These issues are temporary and can be mitigated through a proper training & safety mechanism. In other terms, natural gas and coal combustion process requires different flame intensity. The natural gas can be heated at 100^0C less than Coal combustion. Due to the heat transfer by thermal radiation, a gas heat energy less luminates as compared to the solid fuel flames due to being solid particles more radiation sensitive. Observing the apparent higher convenience and

very minimal operational issues, natural gas adoption for cement industry in North America appeared to be the best alternatives of coal. To put more emphasize on understanding the possible outcomes, challenges, and socio- economic impact of the conversion, the chapter has undertaken a case study of 'Coal to natural gas conversion in cement industry of North America. The facts & findings revealed in the study would unknot the major aspects, assisting cement manufacturers, scholars, and other contributories in the relative field.

- **North America cement energy use**

The northern hemisphere of United Nation formerly recognized "North America, comprises many countries. Considering the main three countries under NAFTA "The Mexico, U.S, and Canada" have been the greatest contributories of cement production and consumption. In context of cement industry, the U.S. demand has observed the highest 40% increment as compared to production increase of 27% between 1990 and 2001. For Meeting the shortfall of supply, U.S. has been the major importer of cement from Canada and Mexico, produced 38% and 25 % more over the same period respectively. Consequently, the cement industry has witnessed the phenomenal upsurge of energy consumption during the past years. As the cement process, particularly the calcination of raw materials in kiln captures the highest amount of energy for fuel burning. As a result of which, the cost of production had become the greatest concerns for the cement manufacturers of North America.

- **Solid fuel consumption by the industry**

Cement production was heavily dependent on energy and specifically solid fuel consumption. Many companies in all three countries have taken steps to reduce

their carbon footprints by switching to dry or pre-calcining their processes, or by investing in energy efficient equipment in their cement production process, making it more efficient in terms of energy use. Over the past decade, the United States' output appears to have increased slightly. As a whole, the cement industries in Canada and Mexico seemed to be more efficient. On the other hand, the emerging environment sustainability regulations, GHGs emissions restrictions, consumer awareness heightened the prevailing concerns of the region. However, to shorten the demand supply gap and ensuring uninterrupted production the U.S. and Mexico shifted from wet to dry kiln technology for being more energy efficient and less pollutant operational system. Nevertheless, the challenges remained on the same page due to highly expensive dry kiln techniques. However,over the last decade, energy efficiency has dramatically improved (energy use per unit of output has decreased). Since the early 1990s, a number of newer plants in Canada were put into operation, partly in response to the increased Demand from the U.S. cement sector. Preheating and/or pre-calcining equipment's have been common in Mexican cement plants. Still, the efficiency gains of the early 1990s could not sustained the same pace and growth. Consequently, a slight decline was captured in energy efficiency scale in recent years, mainly due to the shift to the petroleum coke (Presented in below table).

Table 2: USA & Canada Energy consumption v/s Energy efficiency

Year	U.S. Energy Consumption (TJs) (1)	Estimated Energy Efficiency (TJs per Thousand Metric Tonne)	Mexican Energy Consumption (TJs) (2)	Mexican Estimated Energy Efficiency (TJs per Thousand Metric Tonne)	Canadian Energy Consumption (TJs)	Canadian Estimated Energy Efficiency (TJs per Thousand Metric Tonne)
2010	303,647	5.06	100,532	4.22	58,909	5.32
2011	326,564	5.65	104,872	4.18	50,985	5.40
2012	310,868	5.10	112,643	4.19	51,485	5.99
2013	353,715	5.26	110,856	4.03	53,215	5.73
2014	362,259	5.30	107,554	3.58	53,311	5.29
2015	388,889	5.69	91,593	3.82	61,005	5.76

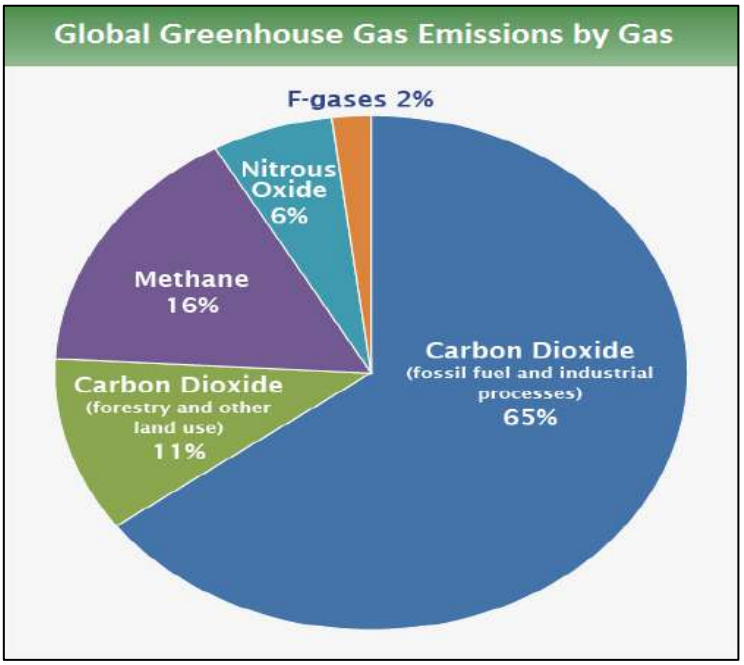
2016	387,138	5.39	98,452	3.88	58,997	5.27
2017	391,115	5.24	96,609	3.51	57,746	4.90
2018	408,526	5.34	105,235	3.79	63,752	5.24
2019	436,768	5.63	96,890	3.29	67,013	5.30
2020	440,348	5.54	118,284	3.73	64,043	5.02
2021	426,301	5.36	116,164	3.88	NA	NA
2010-21 % Change (3)	**40.39%**	**5.93%**	**15.55%**	**-8.06%**	**8.72%**	**-5.64%**
2010-21 % Change (3)	**20.52%**	**1.90%**	**4.79%**	**-3.72**	**20.35%**	**-12.39%**

Source: International Energy Agency (2021)

❖ **Key Challenges**

a) GHGs emission

The cement industries in U.S. exposed to the greatest quantity of GHGs release, similar to the % amount of coal consumption, which as compared to Canada was double of the total emission. The US Toxics Release Inventory (TRI) reported that "the cement industry is the fourth-largest emitter of dioxins and furans, and accounts for about nine percent of all air emissions".



Source: "IPCC (2014) Exit based on global emissions from 2010".

Figure 4: Global Greenhouse Gas Emissions

The above pie chart retrieved from EPA clearly demonstrates that Industrial process, accounting 65% of total GHGs emission, have been the prime contributories among other sectors over the last decade. The increased production and switch from fuel oil to petroleum coke were among the major arguments of the humongous release of GHGs, causing ruinous impact on biodiversity, and ecological environment.

b. Emission Standards

Observing the phenomena, the U.S. and Mexico adopted the emission parameters for neutralizing the hazardous impact of cement kilns. Notably, the standards for dioxins and furnace emissions were of the greatest concerns for all three countries. However, the cement industries in U.S. applied sophisticated measures to kiln flamed hazardous waste, expected to lessen the dioxin release by approx. 40%. But as compared to the other "incinerators of hazardous waste" standards, the kiln burning waste standards in the region of North America remained less vital during the last decade.

c. Cement kiln Dust

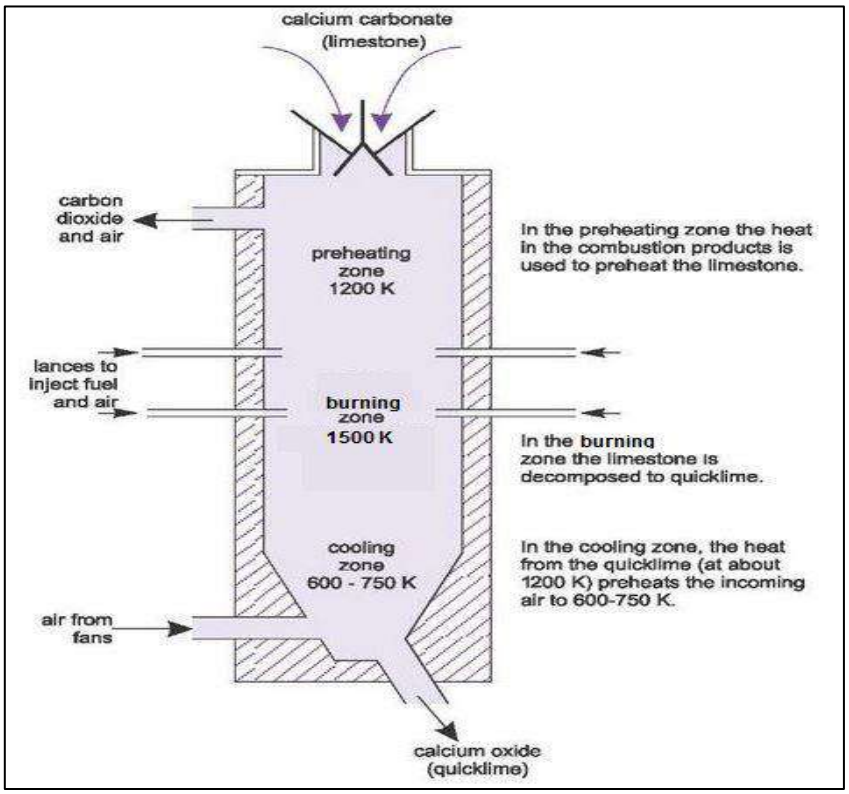
The CKD standards in the study region have so far been ill-defined. The cement kiln dust as one of the major byproducts of cement, was the greatest concerns for the environmental regulatory. Despite witnessing its catastrophic impact on air, ground and surface water, the Environment Protection Agency (EPA) waited long for the further management practices. While, studies found that natural gas heat produces comparatively less amount of CKD. These facts forcibly encouraged the concerned Government and cement facilitators towards the coal-to-gas conversion in North America.

❖ **Natural Gas implantation in North America**

The emerging trend in North America energy market witnessed the lower natural gas prices, capturing the cement manufacturers' attention as the best suitable short term fuel conversion alternative. The particular region developed the advanced techniques, concerning the degrading efficiency of traditional coal plants, the excessive restructuring cost and ambiguous practices failed to achieve the desired results. Many studies expressed that Natural Gas while comparing the physical and chemical properties with the solid fuels reflected impeccable satisfactory results. The study attempts to enlighten the crucial findings, highlighting economic and environmental properties between coal and natural gas exploring various dimensions of combustion, the kiln adjustment, and calcination etc.

- The chemical properties of Natural Gas are such that it contains high carbon and hydrogen content, causing the high calorific value but lower carbon to hydrogen proportion makes it emitting lessor CO2 than coal for the same material input. Moreover, due to being highly sensitive to the radiative energy, the excessive heat is lost in coal combustion while natural gas is preferable, showing high capacity of retained energy. However, while switching from coal to gas the wall temperature is reduced but the very intense and compact nature of gas can cause the corresponding wall hot spot, because of the flame impact. To avoid the serious coating issues on the wall and lowering the flame, the natural gas injection speed can be hugely increased to (200-300 m/s) which, in coal burning is not possible. Thus, conversion from coal to gas might save the primary air fan cost and energy.
- **Increase in clinker production capacity**: Considering the mass combustion capacity of 3000 t/day calciner kiln with the energy injection of 260MW,

generally the products rang in natural gas remains less. Through reducing the volumetric air flow of O2 by 4% to 1.5% while existing calciner the per day clinker production capacity can significantly be increased by 5% to 10% as compared to the coal. Further, in addition to the capacity expansion the grinding cost can be optimized by adopting the natural gas.



Source: World Cement August 2019

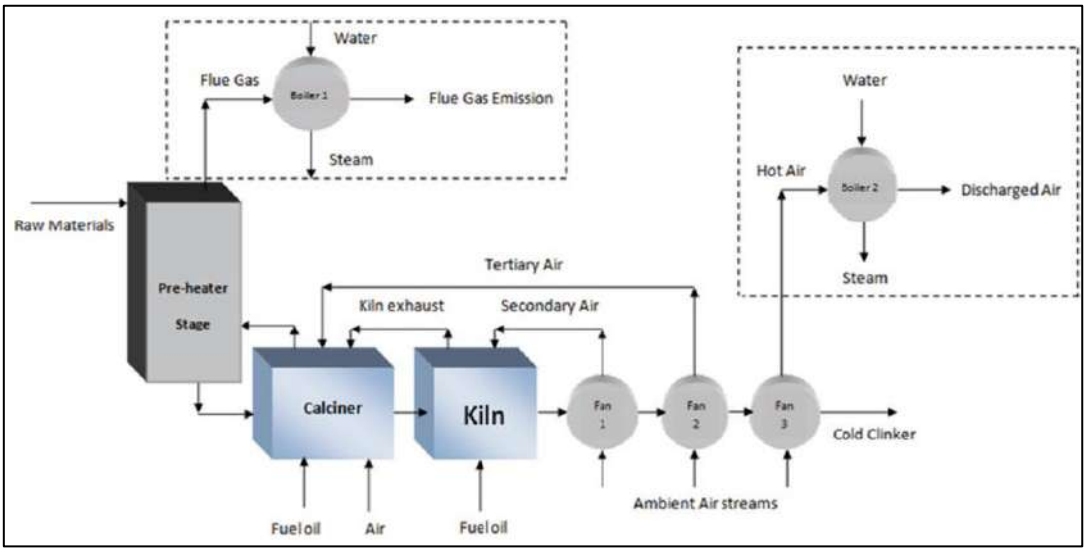
Figure 5: Calciner geometry

- **Raw material modification –** In clinker process, many substances such as sulfur, silica etc. become crucial for the cement strength which while burning kiln by natural gas are hardly traceable. In contrast of which, in coal combustion these compounds are found in the fuel ash in significant amount. Considering the shortfall, some raw material adjustment is required in natural gas processing. Moreover, the cement quality further can be improved mixing gypsum at the grinding stage.

- **Combustion modification in natural gas plant –** Having a relative lighter hydrocarbons fraction as compared to the coal, natural gas instantly lights up when mixed with the material and oxides. On the other side, coal contains a critical structure of lighter and heavier hydrocarbons released while ignition, firstly in the form of droplets of solid particles which thereby increasing the temperature turned into heavier hydrocarbon forms. The particular process releases 'tars' which then converted into ash by moving them through a 'chain-breakup process'. Further, a detailed understanding of various heat transfer scenarios such as "counter flowing, coflowing streams, and residence time variance" is required while switching from coal to natural gas combustion process.

- **Thermal substitution rate (TSR)** - To produce the clinker at acceptable composition, an intense, low flame lit up kiln is essential. Which in case of natural gas burning is attainable by gearing up the thermal substitution rate (TSR) up to 30% and thereby required a minimal burner adjustment. While, the coal combustion pertains comparatively higher TSR, accounting for the burner and kiln modifications mandatorily.

- **Natural gas plant in practice**- In order to examining the natural gas-fired kiln production efficiency, two separate plants were kept under observation. Where plant A was initiated with 50% NG TSR with very minimal changes to the kiln burner setting and slightly reducing its momentum from 8 N/MW to 5 N/MW. The variation helped in increasing the length of the flame and moved the kiln coating upwards. Additionally, by using the 'mid kiln tire injection' the stake emission of NOx and CO decreased to the minimal. Eventually, the overall production reduced by 5% with 50% natural gas TSR in plant A. On the other hand, the coal to gas conversion required a steady and less intense flame in a long-wet kiln. As a result of which the production increased to 10% with minimal decline in kiln backend temperature while dust losses reduced up to 50% in plant B.



Source: World Cement August 2019

Figure 6: Natural gas injected kilning process

- Apart from these studies, another natural gas plant observation in North America demonstrates that in the short residence time of 1.5 seconds, the exit temperature in case of 100% natural gas burning slightly hiked as compared to the conventional coal. Moreover, the facts revealed that due to the repetitive flow of territory air and calciner exit the chances of short circuiting would be higher in the traditional coal fired setting. It took many years to modify the burnouts of coal particles, caused by stratification issue that would be minimized in natural gas- fired settings.

- **Performance analysis-** The above empirical study, considering coal to gas optimality of selected number of cement plants in North America expresses verified facts, benefiting the further researches. It reveals that:

i. The coal fired kiln and calciner process is possible to be replaced with highly intensive natural gas substitution even with negligible detrimental effects. Further, through setting up of highly turbulent intense gas flame can be compensated with the lower radiative heat transmission of natural gas. Besides, increased NOx emission in clinker can subsequently be neutralized by newly designed 'in-line calciner' in gas fired plant.

ii. Natural gas firing would be benefiting in countering the deposits build up and SO3 cycle problems, which in coal combustion add up bulky GHGs emission due to incomplete burnout till the kiln exit.

iii. Calciner with shorter residence time or with lack of O2 adversely affects the coal burning intensity due to incomplete combustion, not evident in natural gas fired plant. The combustion optimization in natural gas system further leads to production increase by 5 to 10%, lower fuel consumption, energy cost savings by lowering handling and grinding cost, and reduced dust losses.

- **Regulatory Standards ("Environmental Side Agreement, the CEC and Cement")**

  - "The North American Agreement for Environmental Cooperation (NAAEC)" was set up by the concerned Government for the effective enforcement of environment in relative cement industries. In 1995, the commission for environment cooperation (CEC) launched a project named "the Sound Management of Chemicals (SMOC) Project" directing the integrated efforts of the three Governments (U.S., Mexico, Canada) towards reducing the outline production and organic pollutants such as mercury, furans, dioxins. In 1999, the plan further included the recommendations regarding technological advancements, controlling strategies and measures to detect and prevent the hazardous substances at kilning process.

  - In addition to this, the CEC successfully initiated a "NARAP on Environmental Monitoring and Assessment" networking program in June 2002, focusing on the critical and consistent monitoring on the environmental contaminants.

  - Studies revealed that due to the absence of practicality aforementioned environmental regulations "the cement industry has until now allowed cement manufacturers significant freedom in their choice of fuels and pollution control equipment".

  - Recently, U.S. regulatory officials have announced more stringent emission standards particularly for kiln burning solid hazardous wastes while Mexico has declared the same irrespective of the fuel type which yet to be enforced.

- Observing the phenomena, some of the common suggestions have been put forth in recent researches:

    a. "Cement kilns burning hazardous wastes should be regulated as hazardous waste disposal facilities

    b. Energy efficiency standards and greenhouse emission standards for the cement sector should be adopted in all three countries.

    c. The CEC should initiate a dialogue about the burning of alternative wastes in cement kilns with a specific focus on dioxin and furan emissions and the control of CKD.

    d. The CEC should continue to strengthen its Sound Management of Chemicals program to emphasize a North American Management Strategy of hazardous wastes and reduction of dioxin and clinker emissions.

Overall Assessment

The study contemplates the facts related to the major shift in fuel use by the main North American countries 'U.S., Mexico, Canada' during last ten years. Likewise, the U.S., kilns in the Mexico have surpassed the high dependency on the coal and inclined towards more to renewable fuels such as natural gas. While, Canada has been less interested to the fuel shift in cement industry, hence coal consumption remained the same. A few years back, Mexico has signed the "Stockholm Convention, calling for the control and phase-out of the production of dioxins and furans" but still being failed in industrial emission controlling measures. Apart from this, the cement industry in all three countries has expanded the range of alternative fuels ("tires, solid hazardous waste and liquid hazardous and non-hazardous wastes") where U.S. and Mexico emphasized more on natural gas, Canada has continued with tire and other hazardous wastes. Surprisingly, despite the industry's objections, "Cement facilities burning hazardous wastes as fuels in Canada continue to be approved and regulated as hazardous waste disposal facilities". The reports also found that the emission standards for hazardous chemicals in Canada, introduced by CCPE in 1999 have yet to be implemented. Moreover, studies found that the type of fuel used by cement facilities in North America regions, is highly ascertained by their price and availability rather than the energy efficiency or sustainability motives. Nonetheless, the consolidation impact of

cement industries in U.S. and Mexico, on the shift to natural gas-fired plant is subject to new insights in future studies.

4.14.3 Evidences from Nigeria

- **Background of Nigerian cement industry**

The modern era is far more implicating than ever before in terms environmental degradation, biodiversity loss, global warming, climate change and is being assumed to be worsen in the coming years. Over exploitation of natural resources and incessant emission of many lethal substances, polluting the environment have been the major causes for the issue. The global phenomena of environment protection and its sustainability have become the prime concern for the Governments across the world. Thus, Coal energy consumption in industries is causing catastrophic impact on nature, hence switching to another alternative non-conventional fuels. In Nigeria, the non- conventional alternatives such as biomass, fuel oil, natural gas etc. are emerging as the better alternatives for coal -fired power plants in terms of physio-chemical properties, GHGs emissions, cost and availability etc. The trend is evolving much rapidly than before, particularly in the industries worldwide. As a result, "Between 2011 and 2019, 121 coal-fired units in the US were considered to burn other types of fuel, according to the US Energy Information Administration (EIA)". Amid in Canada, a coal to gas conversion program " Trans Alta" based in Alberta has been initiated, aiming to restructure the traditional coal units to combined cycle of gas turbines and also replacing with the 100% natural gas plant (Modern, 2020).

Likewise, a recent article reveals that "China is targeting to increase the energy consumption proportion of natural gas from 5.9% in 2015 to ~10% in 2020, and ~15% in 2030. China's objective to "make the skies blue again", through its 13th Five-Year Energy Development Plan which has introduced a mandatory target to promote "coal-to-gas" conversions as the primary measure to fight pollution" (Ho, 2019)

The present chapter through representing a case study of coal to gas conversion scenario of cement industries in Nigeria has been critically discussed. The main objective of the study is to find out the major steps taken by Nigerian cement sector while switching from coal to other renewable energy options. Besides, the chapter will also demonstrate the comparative analysis of coal and gas, the major untapped aspects, causing trouble to the conversion or implementation sequences.

And eventually, it would present the best substitute available, considering all crucial aspects of cement industry energy use.

Cement, being among the most fundamental commodity in constructional activities, is produced over 150 countries around the world. Experts state the cement production to be accelerated countries. Surprisingly in 2006, Asia was seen to capture around 70 % of the total world's production ("47.4% at much higher pace in next coming decades due to increasing economic demand in developing in China, 6.2% in India, 2.7% in Japan and 13.2% in other Asian countries and about 13.4% in Europe").

Meanwhile, Nigeria grew its cement manufacturing over 2 to 17 million tons during the same period (2002-2011). The country expanded its cement export many fold by setting up "Ibeshe cement factory by Dangote Group (commissioned in February, 2012)". Through this, the production observed a hike of 39.4 million metric tons per annum which was directed to "Economic Community of West African States (ECOWAS) and other neighboring countries". Generally, the cement sector consumes around 12% to 15% of total industrial energy use, highest among others. In Nigeria, the energy related expenditures in cement production comprises approx. 40% to 50% of the total cost. Though, the quality variance and production of cement determines the amount of electricity spent on each ton. Particularly, the kilns processing phase consumed the highest quantity of fuel oil or coal or natural gas. However, Nigerian cement industry had been dependent mostly on coal-fired power plants due to dearth of natural gas- fired plants particularly in southern region till 2012. The high dependency over coal, turned the industry emitting the huge amount of CO2, started confronting many environmental standard restrictions, adversely affecting the production and sales. Apart from this, constant decline in conventional coal plants' efficiency, having average of 40 - 50 years of life span caused overburdened cost for the cement manufacturers. Consequently, excessive cost burden had interrupted the export and thereby occurring threat to country's GDP growth. Though, timely policies & regulations were placed to gear up the supply but humongous energy cost was still the major concern. A research article revealed that in 2005 Nigerian cement sector observed $30 per ton as fuel combustion cost, much higher than the unit cost of $6 per ton in China (Olayinka S. Ohunakin, 2013). Considering the high energy cost contribution in the total production cost upliftment, economists found it essential for further alternative fuels adoption for the cement manufacturing process.

Alternative fuels used in cement plants of Nigeria

The cement manufacturing in Nigeria has undergone a major transition in terms of energy generation methods and technologies. The evolving trend of sustainable industrial development, one of the goals in SDG-30, has turned the industries from hazardous emissions towards cleaner and ecofriendly approach for energy utilization. To control the overwhelmed carbon emission from coal combustion, and efficiency upgradation, many cement manufacturers stepped out for alternative fuel options (Sustainable waste management) such as Geo-cycling, Biomass, Natural gas, fuel oil etc. Moreover, substances like "waste lubricants, plastics, used tires and sewage sludge, agricultural biomass and industrial wastes are often proposed as alternative fuels for the cement industry".

The materials are proposed to the process depending upon following factors:

- *Availability.*
- *Physical state of the fuel (solid, liquid, gaseous).*
- *Content of circulating elements (Na, K, Cl, S).*
- *Toxicity (organic compounds, heavy metals).*
- *Composition and content of ash.*
- *Content of volatiles.*
- *Calorific value (typically over 8 MJ/kg is required).*
- *Physical properties (scrap size, density, homogeneity).*
- *Grinding properties.*
- *Humidity content.*

However, an article reveals that except Spent Carbon Lining (SCL), Industrial lubricants, and tires and Natural gas combustion, others were found to have more CO2 emitting intensity even greater than coal. Also, they require heavy feeding meal requirement, attracting excessive cost.

- **Major Initiatives for alternative fuels promotion in Nigeria**

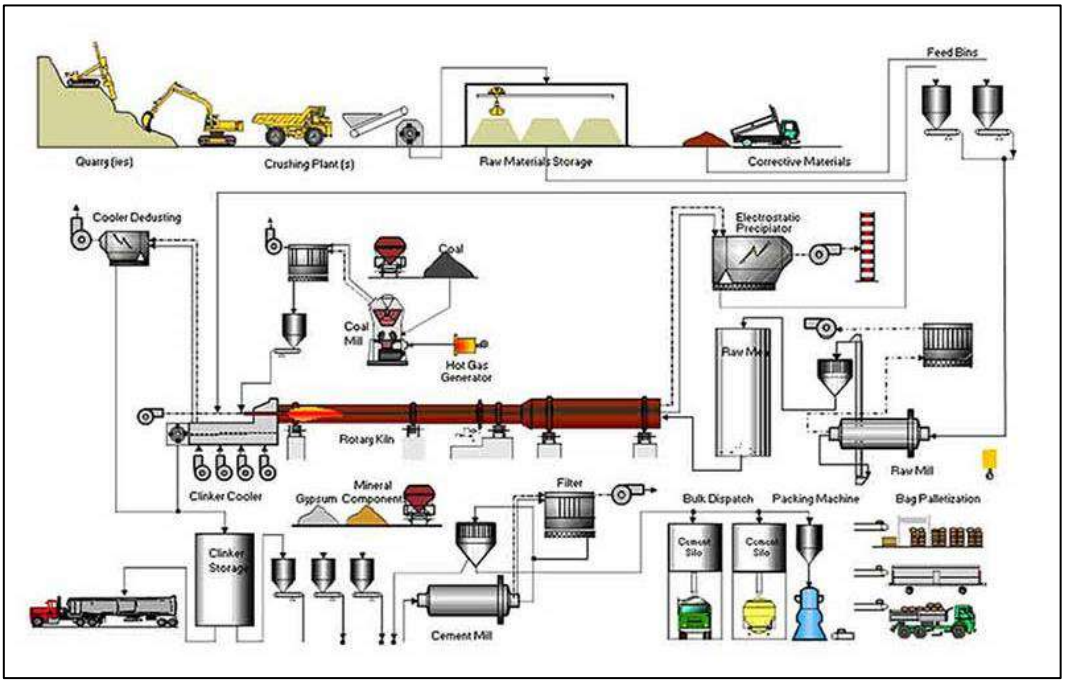
Following are some prime instances, highlighting the various fuels substitutes adopted by Nigerian cement producers:

- The "Lafarge Africa based Ewekoro cement plant", Nigeria reported the alternative substitution rate increased to 46 % during the first quarter of 2017. As a result, the cement producers successfully compensated the coal fuel shortages and excessive cost burden.
- The another "Sagamu plant" had achieved its substitution fuels capacity by 25% in 2017, using the different variants of "palm kernel shells, woodchips, tyres and refuse". However, it is still unclear to know the energy efficiency of these alternatives in critical concept.
- Michel Puchercos the CEO of Lafarge Africa stated that "Our energy optimization plan has proved successful with increased use of alternative fuel to offset coal, oil, and gas shortages. Ewekoro plant migrated from 100% reliance on gas and low pour fuel oil (LPFO) to about 40% use of alternative fuels at the plant group's results for the fourth quarter of 2016. Likewise, the other cement plants namely "Ewekoro 2, Ashaka, Maoming" and the subsidiary of "LafargeHolcim" announced to initiate alternative fuels, coal, and petcoke use at almost all of its Nigerian Cement Plants in 2018.
- In July 2015, "The Ogun State Government" entered into a partnership with the Lafarge Africa towards introducing the Sustainable Waste Management program. The group CEO strongly expressed that the positive consequences of the program would bring ease in lives and boost the economy of country.
- In June 2015, "Aliko Dangote, president of Nigeria's largest cement producer Dangote Group" announced their oil refinery capacity to 650,000 b/day in order to reduce the import of oil fuels and meet the cement production energy needs. Likewise, many such other initiatives have been taken so far using different fuels which reacted diversly depending on their physio-chemical properties, and also affecting the clinker quality and production (Global CemFuels, 2017)

❖ **Process wise Energy consumption in Nigerian cement plants**

Cement is a powdery substance in form of small particles which can be hardened with air or water addition and used majorly in constructional projects of civil engineering, water conservancy, defense and others. Portland cement is most widely used across the world due to its prominent quality. The manufacturing of Portland cement can be processed either through dry process or wet process.

However, the modern industries are preferably adopting the dry process production due to the advantages of energy saving and clean air emittance.



Source: World Cement August 2019

Figure 7: Layout of Cement Manufacturing

- **The Cement Manufacturing dry process consists of following prime steps:**

1) *"Raw material extraction/ Quarry*
2) *Proportioning, Blending, and Grinding*
3) *Pre-heater Phase*
4) *Kiln Phase*
5) *Cooling and Final Grinding*
6) *Packing & Shipping"*

Typically, in Cement manufacturing, the total energy is diversified as 1.9 % for raw grinding, 92.7% for clinker production, and 5.4 % for finish grinding. The amount of energy can be saved by switching fuel alternatives, depending upon their

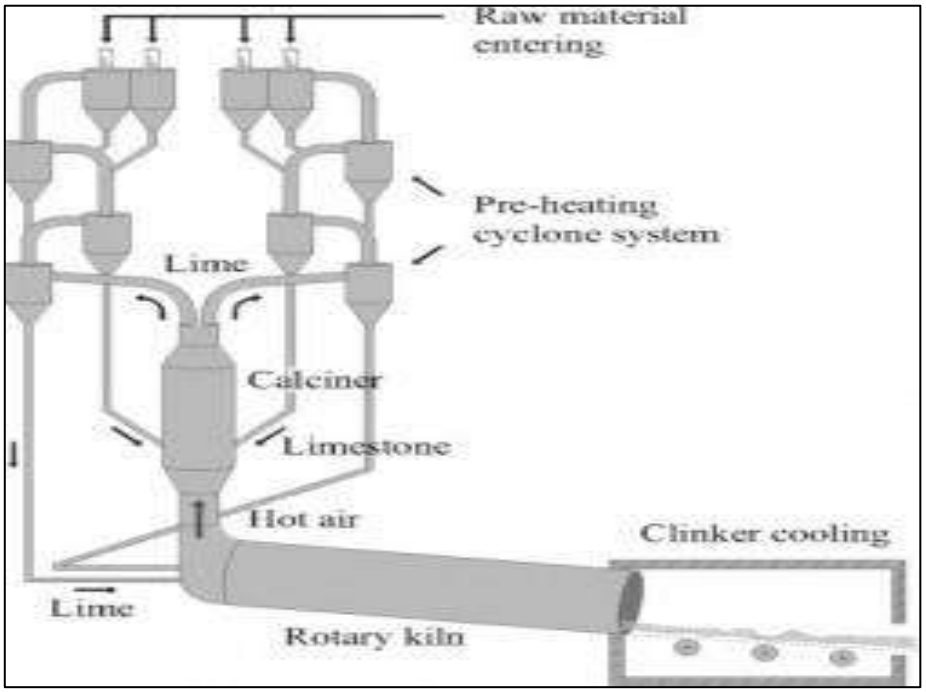
calorific value and physio-chemical characteristic. Hence, the type of fuel determines the GHG emission, cost and energy saving, and product quality.

Phase: I Raw Material Processing

- Considering the dry process, the raw materials are crushed and then dried in a cylindrical drier in order to get the pulverized form which later stored. The separately pulverized dried particles are mixed automatically which then transferred to a kiln for clinker production, consuming about 80% of the total energy used in cement manufacturing. Surprisingly, the primary energy sources for dry process requires 75% of combustion energy and 25 % of electric energy. However, as compared to the wet process, the electric energy requirement is higher in dry process making.

Phase -II Pyro processing:

- Following the sequence, the calcium carbonate ($CaCO_3$) present in the dried mix is decomposed to extract calcium oxides, lime by heating them at about 900^0 C, which in turn emits CO_2, typically known as the Calcination process. Further, to form the clinker, the obtained calcium oxides is reacted with silica, alumina, and ferrous at 1400^0 -1500^0 C temperature. Consequently, the processed kiln is then sent further for cooling and finish grinding. Meanwhile the process, about 81% CO_2 emission is observed (36.8% and 46.3% from coal burning and pyro processing reaction respectively. Though, the emission amount can be reduced by switching from coal to other fuels such as natural gas. Studies reveal that substitution with natural gas not only lesson the carbon emission but it also gears down the total production cost, saves energy, and improve cement quality (Oluwafemi M. Fadayini, 2021).



Source: World Cement August 2019

Figure 8: Kiln Process in Cement Manufacturing

1. Comparative study between coal, natural gas, and oil fuel

The above analysis of cement making process reflects the kiln stage as the highest energy consuming, and carbon emission, concerning the environmental issues as well. Thus, the chapter further examines the coal, natural gas, and oil fuel alternatives for obtaining the most suitable option of energy generation.

Table 3: Alternative fuel options

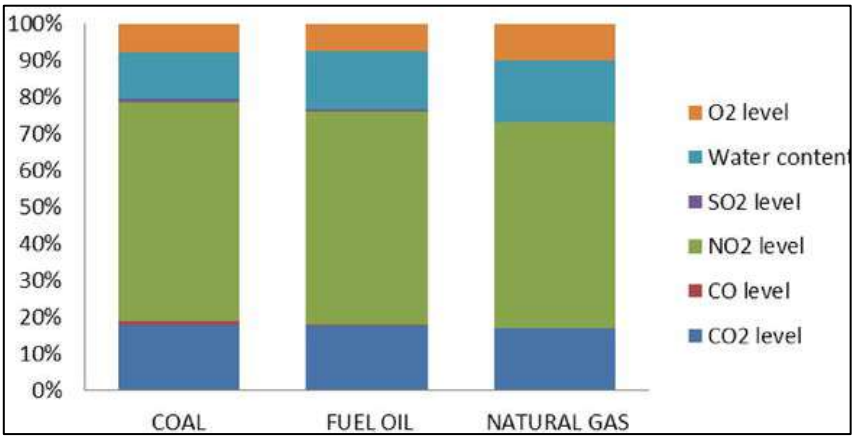
S/N	Fuel	Energy Content (MJ/Kg)
1	Coal	36.3
2	Natural gas	54.0
3	Fuel oil	45.6

Source: "Engineering Toolbox, (2008). Fossil and Alternative Fuels Energy Content. [online] Availableat: https://www.engineeringtoolbox.com/fossil-fuels-energy-content-d_1298.html [Accessed: 23/2/2021]".

The above table expresses Natural gas as having the highest calorific value (54.0 MJ/Kg) while coal stands at the lowest (36.3 MJ/Kg).

Among three fuels, coal is found as the most abundant fossil fuel on the earth and contributes the highest (41%) of world's electricity generation. While fuel oil is extracted from petroleum distillation. In terms of cement kilning heat production, fuel is regarded as "heavy fuel oil, or low pour fuel oil (LPFO)" where heavy fuel is used to "produce electricity, to fire boiler and furnace in industry, notable the cement, pulp, and paper, and to power large marine and other vessels" (Newsroom, 2017).

Likewise, Natural gas is regarded as a cleaner form of fossil fuel, found in plants, animals, algae, and microbes lived millions of years ago. In the emerging time, natural gas is proved to be the essential factor for global development in many aspects. Particularly, it has so far been the best substitute of coal and oil, consisting the highest energy content. The chemical property of Natural gas is such that Hydrocarbons and Methane (CH4) contributes in the heat production while, Ethane, propane (C3H8) makes its density heavier. Nitrogen, Oxygen, and CO2 are the contaminants of the natural gas, present in high concentration (99.9%) of air.



Source: PNGRB 2020

Figure 9: Flue Gas Composition

It is clear from the above table that oxygen and water content is higher in natural gas while it comprises lessor CO2 level than coal and oil. As oxygen plays significant role while combustion of natural gas. The combustion is the consequence of the chemical reaction of burning material and oxygen through a source of ignition. Notably, as compared to coal and gasoline, natural gas combustible mixture, when burned with air releases extremely high ignition temperature of about 1150^0 F. As a result, even with a low resistance period, natural gas can provide higher intensity of heat than coal, reducing energy loss and attaining optimality in clinker mix. Moreover, due to being lighter than air, it can easily be dissipated into air, hence reduces the chances of accidental combustion.

- **Overall Assessment of Nigerian Cement companies fuel adoption**

Considering the study objective, the three leading cement companies in Nigeria have been crucially investigated, concerning their fuel use and consequent results. The companies have been addressed as A, B, C ("Dangote Cement in Obajana, Kogi State; United Cement Company in Calabar, and Nigerian Cement Company, Ebonyi State" respectively).

The findings of the study show that petroleum oil is the most expensive and highly threatening to flora and fauna lives. Although, it is readily available to Nigerian cement industry but considering the apparent peril to the environment, the Government has put across consumption restrictions over it. On the other hand, Coal, however being the cheaper substitute of oil, emits humongous amount of CO2. The catastrophic threat to environment by coal combustion cannot be ignored. Among the selected three companies, factory B was found to be having the cheapest energy consumption cost per ton of cement production, depicting the natural gas as its major source of energy. Whereas, Factory A demonstrated as the most expensive, preferably using the petroleum fuel. The studies shows that natural gas is the cheapest energy source and due to its easy availability in Nigeria, it has been the first choice for cement companies. Moreover, having the natural properties of releasing lessor carbon, it has been regarded as good alternative of coal. Another reason of declining trend of coal energy consumption in Nigeria is due to shutting down the coal mines by Government orders.

The above detailed case study of Nigeria cement plants illustrates many aspects of energy consumption trend and the type of fuel used over the past years. The study indicates that observing the future expedition of environment sustainability, the cement companies in Nigeria are now much into exploring better

alternatives, though expecting lower final production cost through energy saving techniques. The critical investigation of different alternative fuels considering their physio- chemical properties, feeding material requirement, and combustion emission, and cost effectiveness entail different impact on cement production. Where fuels like tire, SCL, industrial lubricants reflect cheaper plantation cost, high pollutant emission is still of the great concern. Though, many giant cement producers are committed to transform into green industrial environment, they are incessantly indulged in programs like 'Sustainable Waste Management'. Apart from this, many cement producers have considered Natural Gas as the best replacement of coal and oil due to its higher favorable characteristics concerning the cost and environment. However, environmentalists regarded it as the temporary energy solution due to its limited availability in future. Also, many experts opine that natural gas is nowhere counter off the GHGs effects of coal combustion as Methane, the most hazardous in GHGs amounts around 33% emission. Despite the fact, it is being assumed as the best alternative for neutralizing short term pollution issue. Additionally, price and availability has played a significant role in determining the fuel adoption in Nigerian cement sector. Thus, the cheaper price and easy availability has promoted the Natural gas adoption in Nigeria over the past time.

4.14.4 Evidences from japan

- **Background of Japanese Cement industry:**

The following case study has been dedicated to find out best possible solutions to the emerging paucity of the conventional energy resources (Coal, oil etc.), debarring the industrial growth. The major focus in the study has been placed on prevailing challenges to the manufacturing units in terms of energy consumption, considering the socioeconomic and environment sustainability repercussions. For the sake of the purpose, a detailed qualitative analysis of the cement manufacturing units in Japan has been outlined. The present study finds out the Natural Gas as a better alternative replacement of fossil fuels energy resources for industries. Also, the limitations of the suggested solutions have been defined in Indian context. At the end, the study highlights some major recommendations as how the suggested alternatives can be successfully implemented in Indian scenario.

The Globalization has opened numerous opportunities for the industries and consequently the economic growth of different countries across the world. Where delimiting boundaries have increased the international inclusion and prosperity, the increasing demand and supply have caused many other challenges such as increased

carbon emission, climate change, global warming and environment degradation. Thus, the present time is crucial to create such a world to ensure incessant industrial growth coupled with environment protection. Many recent studies have found that coal, being one of the largest energy resources, specifically in industrial sector has been the major contributor of CO2 emission. Due to cost efficiency and easy availability, coal has been the prime choice of many developing countries worldwide. Notably, the Cement industry, known for the highest energy consuming sector, emits the greatest number of pollutants in form of CO2, NOx, SOx etc. An article reveals that the sector exhibits approx. 8% of the global carbon emission, causing a threat to the socio-economic serenity. Considering the issue, "Global Cement and Concrete Association (GCCA)", demonstrating 30% of the cement production capacity worldwide has announced the industry's first "Sustainability Guidelines". Besides, "Germany-based Heidelberg Cement" in Norway has initiated a waste based alternative fuel resources as a replacement of coal energy (Yale Environement 360, 2018). Likewise, the US, Nigeria, Mexico, Japan etc. are sincerely moving ahead towards adopting eco-friendly energy resources such as natural gas, biomass, tyre, etc. Though, researches reveal that unlike the developed countries, the implication of advanced technologies is still beyond the reach of developing nations, particularly India. Being the 3rd largest producer of coal in the world, the production-based carbon emission in India has heightened from 500 million tons to 2.5 million tons (1990-2019) (Roser, 2021). Apparently, the Indian cement sector is one of the highest energy intensive industries, depicting (15.60%) of total coal fuel consumption.

On the other hand, among developed nations, in 1950 Japan' s energy consumption need was majorly depended on coal, one third hydroelectricity and rest on oil. Interestingly, by 2001, the contribution of natural gas has increased to 50.2% of the total with a rise in the use of nuclear and oil fuels. Though, minimal domestic reserves of LNG, Japan had been the major importer to meet the rising demand of Gas. While, a new Japanese LNG strategy published in May 2016 envisaged the creation of a liquid market and an international LNG hub in Japan". Surprisingly, the coal energy use declined to 24.3% in 2017 from 50% in 1950 whereas, natural gas use got a hike of 24.6% over the same period and now being used as the prime energy source for the cement sector of Japan.

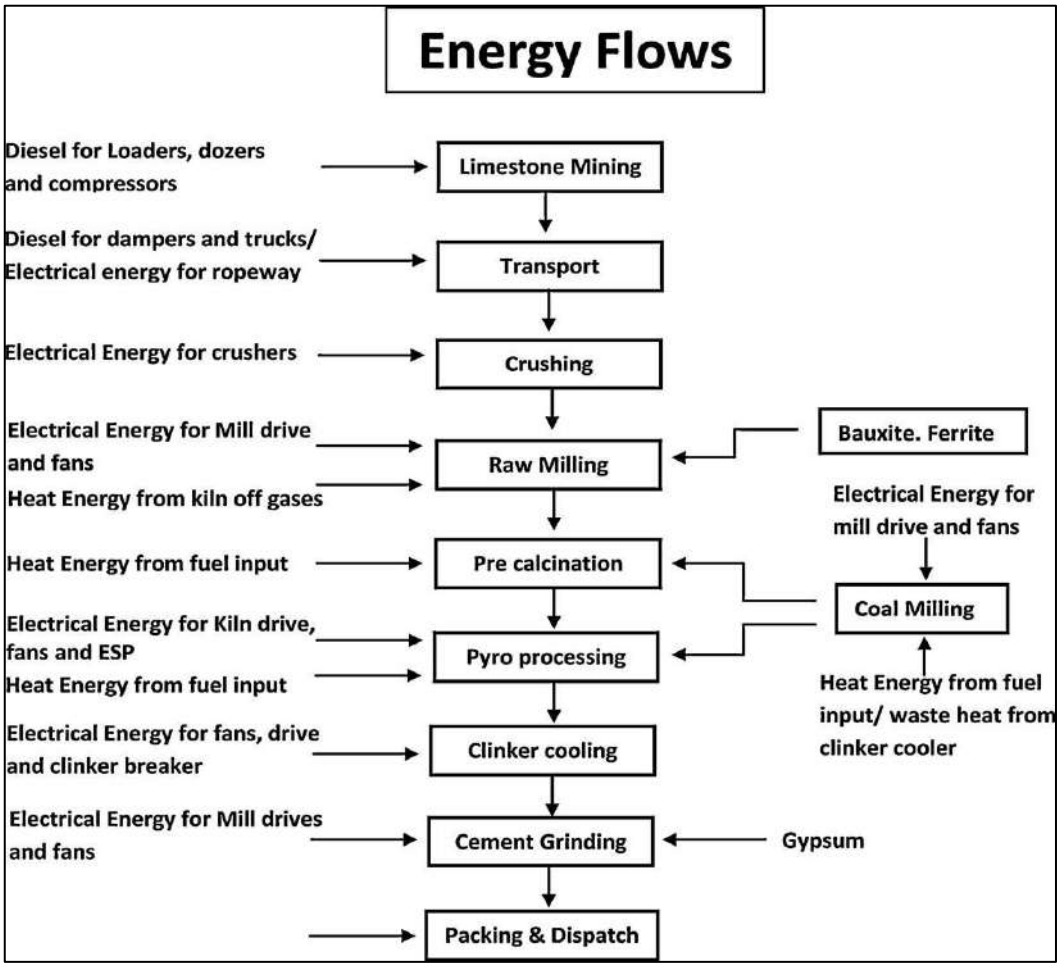
Therefore, the purpose of the present chapter is to crucially look into the overall transformational journey of cement industry in Japan, focusing on the major

challenges, and initiatives in terms of alternative fuels energy adoption. Moreover, based on the comparative analysis, the study throws a light on some of the most popular suitable alternative solutions and recommends the best fit solution in terms of Indian context.

- **Cement Industry in Japan – Demography and assessment**

The Japanese cement sector is one of the ever-growing industries, providing robust growth opportunities to the suppliers and the economy as a whole. The country produces an average of 5043 thousand tons cement of total global production, being on of the giant exporter across different countries. The three leading companies in Japan "Taiheiyo Cement Corporation, Ube-Mitsubishi Cement Corporation and Sumitomo Osaka Cement Company, account for about 80% of this market". The CO2 accounts for almost 4% of the total emission in Japan. (PIECE OF JAPAN , 2021). A report reveals that approx. 75% of energy need in Japanese cement plant was channelized through fossil fuels and remaining 25% from electric energy. Surprisingly, some decades ago, coal accounted for 92% out of total energy requirement and rest part from oil fuel and high-speed diesel in cement manufacturing in Japan. Due to insufficient availability, natural gas was not among the top choices of sector. Though, over the last decade, Japanese Cement Association (JCA) have propounded many advanced clean coal technologies (CCTs), and other alternative energy resources. Some researches demonstrated the process wise energy use in cement plants of Japan and found Pyro-processing as one of the most coal energy consuming stages.

The detailed explanation of energy flows is illustrated below -:



Source: World Cement August 2019

Figure 10: Energy flow in Cement Production

Electrical and thermal energy flow in a cement manufacturing process. The above flow chart depicts that among all stages, pre -calcination and pyro-processing consume both electric and coal energy, accounting for 93% of total fuel consumption. Besides, the emerging methods have shifted to dry process from wet process due to lesser coal energy requirement while more of the electric energy.

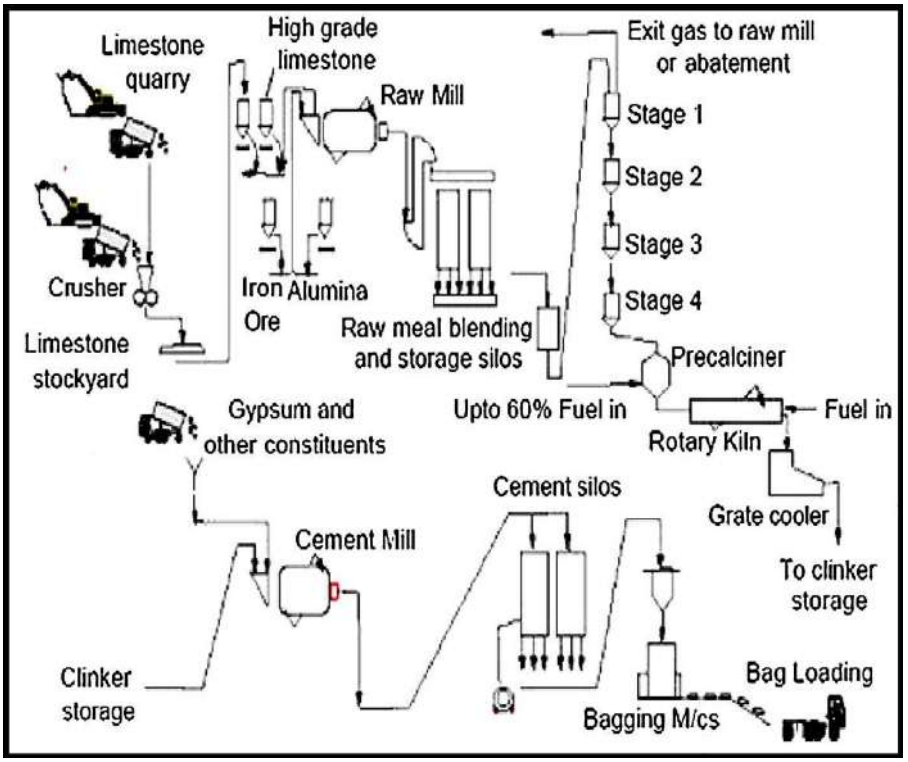
A brief description of cement manufacturing process in Japan

- **Limestone crushing -** Apart from aluminum, silica, iron, and magnesium limestone is the main raw material, which after mixing with silica gives

strength to the cement. Limestone contains about 75- 90% CaCO3 in raw form which after processing through primary and secondary crushers are converted into 25mm size. Generally, the mining and quarrying process mostly consume electric energy and high-speed diesel and oil fuel.

- **Raw Mill –** The obtained raw mix is further transferred into a ball mill or a vertical roller mill (VRM) for finer grinding. The choice between ball mill or VRM depends upon various factors including "moisture content of the raw material, the size of the plant, the abrasiveness of the material, the energy consumption levels, reliability, and economic viability".

- **Blending silos, pre-heating, and kiln -** Blending of raw material is crucial for obtaining less chemical contaminated mixture. Also, increasing the blending additives may reduce the amount of clinker used and consequently the specific energy consumption gets reduced.



Source: World Cement August 2019

Figure 11: Japanese Cement Industry Manufacturing Process

- A pre-heating tower coupled with the kiln make the Clinkering process accomplished. The blended raw material is put into the pre-heated tower, which then goes through a chamber, called pre-calciner. At this stage, the CO2 is disassociated from the mixture. The CO2 -free raw mix then is passed through the Kiln ("60–200 m long with diameters ranging from 3 to 9 m") slowly rotated at 1-2 RPM. At the end shore of kiln, raw mix is diluted with highly excessive temperature, where for flame generation, materials such as biomass, coal, natural gas, and wastes are used in powdered form. Finally, the clinker is obtained at the end of kiln in red hot mixture.

- **Cooling –** The hot clinker is then passed through different kinds of coolers to partially recovering the thermal energy and lowering the temperature from 1500 c to approximately 170 c.

❖ **Coal energy consumption in cement production**

According to a report, despite having the greatest environmental threats, coal energy covers around 90% of the global energy consumption requirement. Notably, the analysis of the major cement companies in Japan demonstrates the fact that it takes about 200-450kg coal energy to produce 1t of cement. Thus, the production cost of cement becomes extremely expensive due to being highly energy intensive. Though, the abundance availability and cheaper than other fossil fuels, coal is still being extensively used in cement manufacturing. It was found that Japan had been facing the coal scarcity and been the third largest importer (188 Mt) in 2014 after China and India, which made it extremely expensive for the cement sector. Considering the emerging cost burden, scarcity, and environmental issues, the Japan Cement Association took major initiatives regarding traditional coal plants replacements, Alternative renewable fuels, or other technological advancements such as shifting to dry process, waste management strategies, energy conservation techniques etc.

Major initiatives as alternative fuels and technologies in Japan

I. Old Kiln System replacement – The analysis of the above selected cement companies illustrates that over the past years, cement manufacturers have replaced their old kiln systems with the advanced "suspension preheater kiln (SP kiln) or suspension preheater kiln with a precalciner (NSP kiln)". Notably, these kilns were found to be far more energy efficient and enabled mass production, which cut down the coal energy use by about 40% as compared to

the wet process. Moreover, the kiln capacity of SP and NSP kilns were increased by 3.3 times and 4.9 times respectively than the older process. Though, the substitution hardly reduced the overall cost of production due to higher cost of replacements.

II. The specific electricity consumption – During 1980's, new technologies in the form of Vertical roller mill (VRM) were introduced at the raw material processing and finishing stage. These improved the product quality and suppressed the need of specific electric energy. Surprisingly, the innovative waste management techniques have raised up the electric energy need in recent years. An article reveals that "Electric power by on-site power generation including power generated by waste heat recovery (WHR) covers more than 60% of the total electricity consumption in cement sector of Japan.

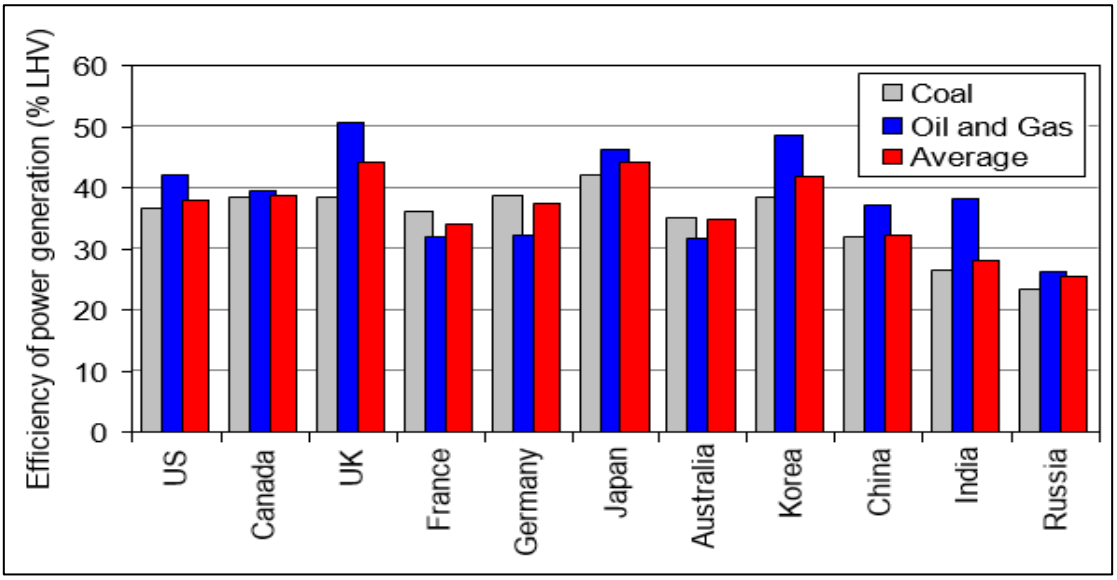
III. In order to fossil fuel (Coal) energy consumption, "Sumitomo Osaka Cement subsidiary Hachinohe Cement" in Japan has started using heavy oil and woodchips obtained from the wreck of a ship from nearby located port. The company planned to substitute coal fuel with the waste as refused- derived fuel (RDF) for cement manufacturing. Notably, on 11 august, 2021 the officials revealed that the production cost was reduced and also carbon emission was slightly declined with the use of alternative fuels. However, the replacement is being considered as just a temporary solution and less suitable from the financial framework.

IV. "Palm kernel shells (PKS)", currently being one of the cheapest biomass energy products in cement sector of Japan. As most of the cement companies were having the lesser output in exchange of the higher input of coal fuel, which ultimately led them towards incessant losses as troubling with the extremely higher cost and lessor production efficiency. Concerning the issue, "Taiheiyo Cement", Japan installed three BWZ bucket elevators, particularly for facilitating the transportation of "palm kernel shells (PKS) and palm empty fruit bunches (EFB)" as alternative fuels at its Biomass power plant. However, the substitution was not seen sustaining in longer term due to excessive "moisture content, calorific value and impurities or contaminants and cost of transportation.

V. In order to increase the alternative fuels substitution rate with coal fuels, ASO cement (Japan) set up a plant, disposing 160t/day plastic waste. The company intended to cut down the excessive cost of coal burning in cement production

and to extend the substitution rate up to 50% by 2020. Notably, due to extremely higher setup and maintence cost of the waste plant the alternative was not found as the best replacement of coal.

VI. As the Natural Gas reserves are scattered throughout the world, and are insufficiently available in domestic market still, it is being considered the most cogenerated renewable fuel by the Japanese cement industry. Studies suggest that the LNG is expected to remain for longer than the oil fuel and illuminating as the prime energy source for the future. Apart from its existing application as energy source and large-scale plants, Natural gas has come up as the marvelous spread of cogeneration systems, particularly for cement plants. Interestingly, the share of natural gas in Japan as the primary energy supply depicts the third largest global contributor after U.S.A. and Europe.

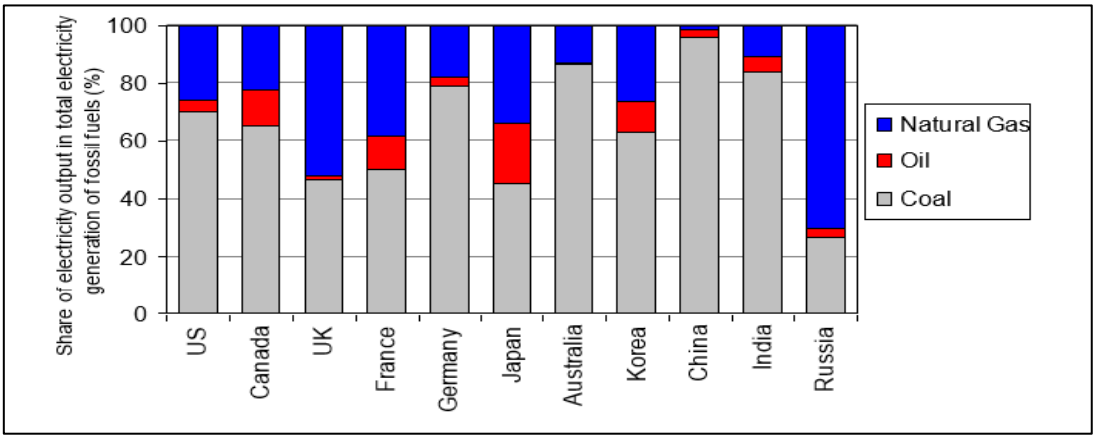


Source: Oil and Gas Journal 2019

Figure 12: Comparison of energy efficiency of fossil fueled power generation of 2018 by region

The above bar graph depicts the position of major countries in terms of energy efficiency of fossil fuels. Among all, U.K. is exhibiting more than 50% of oil and natural gas in energy efficiency, whereas, Japan comes up at third position (around 45%) of gas cover, which is higher than its coal energy efficiency output. Notably, India stands at fifth rank, depicting the higher natural gas energy efficiency

than coal. In a nutshell, the above analysis demonstrates a strong picture of Japan in terms of Natural gas energy viability.



Source: Oil and Gas Journal 2019

Figure 13: Comparison of fossil fuel share for power generation of 2018 by region

Notably, it is clear from the above graph that Japan is the 4th largest player (65%) after Russia, UK, and France, concerning the share of natural gas out of total electricity of fossil fuels.

According to an article, the whole amount of natural gas (including import and domestic production) is distributed in the residential, industrial, commercial, and wholesale sector where it was found that industrial sector has been consuming the highest amount of gas as the main energy fuel (3599 million/m3).

Natural Gas – as an alternative fuel in Cement Industry

Natural gas has been considered as the primary alternative of coal energy due to its numerous chemical and cost related attributes. Surprisingly, it came out as a boon for Japanese cement industry as it featured significantly lower CO2 emission per unit of energy. A comparative analysis of top cement companies in Japan illustrated that those, who primarily used natural gas as a replacement of coal, have been exhibiting lower carbon combustion, medium calorific value and lower moisture content, despite having old kilns and other technologies. The main objective behind the conversion from coal to gas was to obtain the economic and environmental sustainability across the industry.

The shift from coal to gas brought up as one of the most viable cement industries of Japan as the renewable fuel (natural gas) comprehensively supported the adoption of new dry kilns technologies. Apart from preheaters and percalines, all other technologies were phased out, not collaborating the new fuel substitution. One of the selected cement companies (Taheiyo cement corporation), observed an upsurge of energy intensity of 3100 MJ /t clinker after the substitution from coal.

Role of Natural gas - CO2 reduction in cement production

Surprisingly, the facts revealed that unlike the other industries, the fuel consumption in cement industry was not found to be the major driver of CO2 emission. The major part of CO2 emission (more than 50%) was observed at calcination stage where limestone is converted into lime ("CaCO3 → CaO + CO2") and about 40% of the CO2 emission was due to burning coal of high calorific value. Coal happened to be among the prime component among all resources of thermal energy production (including oil, natural gas, biomass), which emphasized the kiln reaction at 1,450 C heat and an emission of "1,700 MJ / t" which strikingly cut down to a lower energy requirement (1100^0C) with the adoption natural gas energy. Moreover, the cement companies witnessed an overall decline in a production cost from 30% to 50% over the last 5 years. Though, the increasing use of electric energy in waste material substitution as alternative fuel have reduced the CO2 content and the demand of natural gas in the cement sector as well (Osako, 2012)

As the above findings suggest that at the preheating stage about 40% to 60% fossil fuel was burned followed by the calcination of raw mix. The natural gas fuel adoption considerably increased the specific daily output for a kiln as compared to the other fuels. Many studies expressed that to achieve higher thermal efficiency and optimal production and cost, Natural gas has shown up as the most popular fuel for cement production (World Business Council for Sustainable Development, 2009).

- **Overall Assessment**

It's quite evident from above analysis that Japan, being a developed nation has come over tremendous transformation, concerning its cement production activities. Japan places world's fourth largest cement producer but on the same time the country is known as the 2nd largest one in CO2 emission reduction. Notably, a number of green initiatives have been introduced by Japan cement association (JCA) in order to promote economic and environmental viability of cement sector. The industry observed a significant reduction after the substitution of fossil fuels by

various alternative fuels namely biomass, natural gas, plastic waste. Moreover, the new green energy efficiency technologies (SP, NP preheaters, Dry process making) have not only improved the kiln quality but cut down the total production cost, comprising major part of energy use cost. Surprisingly, among all alternatives Natural Gas energy consumption has come up as the most viable and feasible solution of the coal energy. Along with, many green benefits, the adoption of NG is being considered as the most prominent fuel, observing the future trends. Though, release of excessive methane and scattered availability are still the factors of higher cost and pollution in some countries.

Use of Alternative fuels in Cement Industry

As the emission norms are getting stringent day by day and the pollution on the rise in the country there has been a promotion of alternative fuels in every sector of the industry in order to reduce pollution and reduce the dependability on the fossil fuels. There are various alternative fuels that are available for the cement industry, which can help the industry in improving its green footprint and reducing emissions. Below diagram shows the waste generated from the cement industry.

Table 4: Alternative Fuels Uses

Raw Materials	Waste Material	Industrial Sources
Clay mineral / Al_2O_3	Coating residues Aluminium recycling sludge	Foundries Aluminium industry
Limestone / $CaCO_3$	Industrial lime Lime sludge	Neutralization process Sewage treatment
Silicates / SiO_2	Foundry sand Contaminate soil	Foundries Soil remediation
Iron-oxide / Fe_2O_3	Roasted pyrite Mechanical sludge Red sludge	Metal surface treatment Metal industry Industrial waste water treatment
Si-Al-Ca-Fe	Fl ashes Crushed sand	Incinerator Foundries
Sulphur	Gypsum from gas desulphuriza-tion Chemical gypsum	Incineration Neutralization process
Fluorine	CaF2 filter sludge	Aluminium industry

Source: CMA Statista 2022

Co handling of different squanders like waste carbon from pharmaceutical enterprises, paint slop from Car enterprises, utilized !res and isolated fractions from civil waste in concrete industry as Alternative Fuels for delivering clinker supplanting coal is another high potential zone of enthusiasm for the Indian Cement industry. Right now warm vitality consumption represents 31 % of the GHG outflows. Regardless of whether endeavors are taken to supplant the conventional non-renewable energy source with any of the squanders or exchange fuel by no less

than 10 %, this will bring about lessening the outflows by around 22 kg CO_2/MT cement.

Uncalled for collection and segregation frameworks, absence of pre-handling office for converting variable quality waste into uniform quality AFRs, nonattendance of any incentives/credits/empowering arrangements for administration of squanders in cement furnace and absence of innovative and operating mindfulness on co professional cessing are a portion of the zones of concern the Indian concrete industry is confronting today in boundless adoption of interchange energizes and crude materials in cement producing. Biomass utilization as Alternative Fuel for warm substitution could be a noteworthy zone for the Indian cement industry.

Indian Cement industry is a long ways behind its European/Japanese partners in use of Alternative Powers and crude materials. A portion of the European nations have a warm substitution rate as high as around 4o%12 in their concrete assembling facilities. CII's estimates demonstrate that the Thermal substitution in Indian concrete industry is under 2%. India still has far to go in guaranteeing more prominent substitution of AFRs, resulting in sizable conservation of common materials and petroleum derivatives.

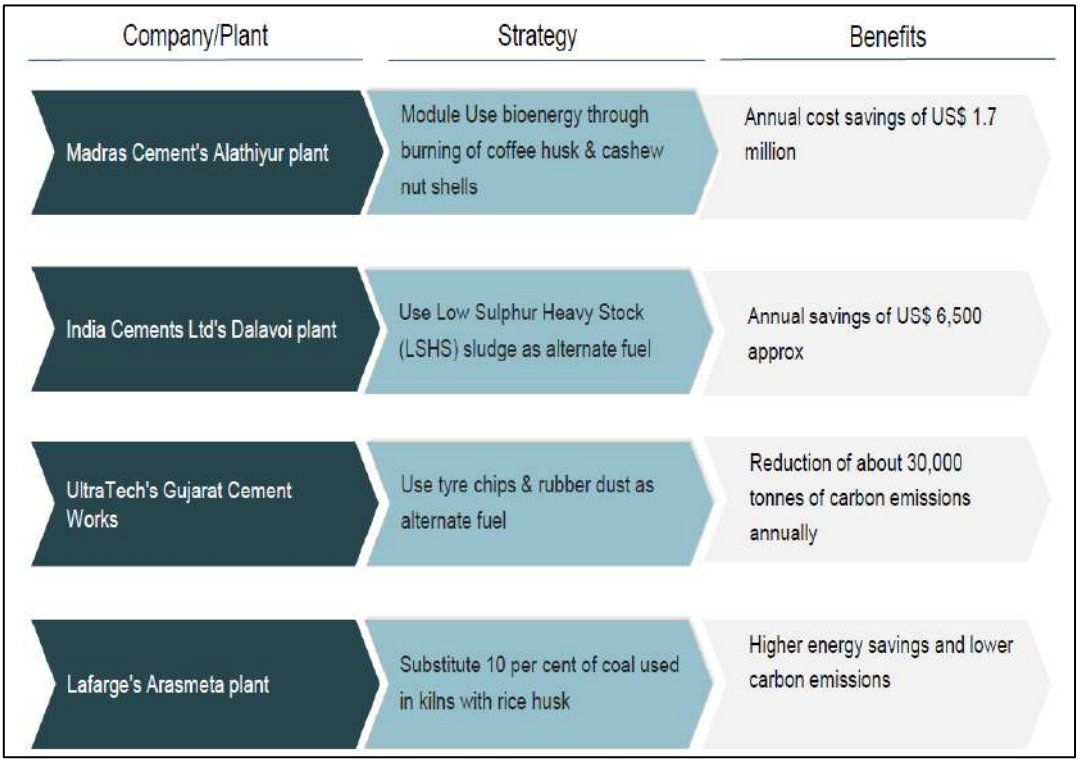
Table 5: Some Alternative Fuels

Over view of key combustion characteristics and typical substitution rates of a variety of alternative fuels used for cement manufacturing

Fuel	Substitution Rate (%)	Lower heat value (G.J/DT)	Moisture or water content (%)	Ash Content (%)	C content (% by dry wt)	Carbon Emissions Factor (Ton C/ ton of fuel)	Co2 emissions offset /t of coal replacement	Associated emissions	Data Source
Agriculture Biomass									
Rice Husk	35	13.2-16.2	10	20.6	38.80	0.35	0.0	Cl	(Mansaray1997; Jenkins,Baxter et al.1998 Demirbas 2003)
Wheat Straw	20	15.8-18.2	7.3-14.2 (7.3, 12, 14.2)	4.5-8.9	44.9-48.8	0.42	0.2		(Mansaray1997; Jenkins,Baxter et al.1998;Demirbas2003; Asian Development Bank 2006;McIlveen-Wright 2007)
Corn Stover	20	15.4	9.41-35	3.2-7.4	42.5	0.28	-0.6		(Demirbas 2003; ani, Tabil et al. 2004; sian Development Bank 2006)
Sugarcane leaves	20	15.8	<15	7.7	39.8	0.34	-0.1		
Sugarcane (Bagasse)	20	14.4-19.4	10-15	4.2	44.1	0.39	0.4		(Li 2001; Demirbas 2003; Asian Development Bank 2006)
Rapeseed stems	20	16.4	12.6	5.9	45.2	0.39	0.1		
Hazelnut Shells	20	17.5	9.2	3.5	52.9	0.48	0.4		
Palm nut shells	20	11.9	10			0.36	0.7		

Source: CMA Statista 2021

Some successful utilization of alternative fuels in Indian cement industry are as follows:



Source: CMA Statista 2021

Figure 14: Successful implementation of Alternative Fuels in India

The use of alternative fuels can be further understood by the following two case studies.

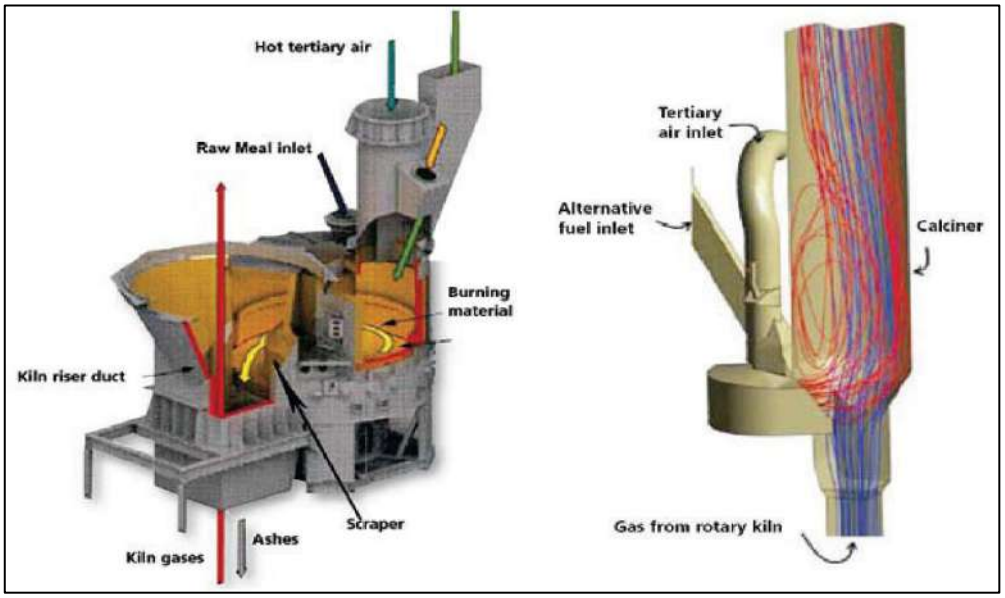
4.14.5 Evidences from India

(a) Common effluent treatment plant sludge as alternative fuel in cement kiln – Binani Cement (India)

Project Details

The Sludge from the Common Effluent Treatment Plant (CETP), Pali is being utilized as a major aspect of organization's Social Responsibility towards condition protection. The muck, a strong perilous waste, contains lethal chemicals, for example, PCBs, dioxins, Persistent organic Contaminations (POPs) and substantial metals like

cadmium, arsenic, zinc, mercury and so on which by ethicalness of being cancer-causing, are to a great degree unsafe for human well-being and condition if arranged improperly into landfills or water bodies. Until the foundation of 'Pali Water Pollution Control Treatment and Research Foundation, the gushing produced by the textile businesses used to be unpredictably arranged into the neighborhood waterways and water bodies making the city's mechanical bunch be proclaimed by CPCB as one of the 14 most critically dirtied regions in the nation.



Source: World Cement August 2019

Figure 15: Sludge treatment process in Binani Cement

Project Benefits

1. The undertaking spares the neighborhood streams and water bodies around Pali from getting contaminated.
2. GHG emanation diminishment because of halfway substitution of petroleum product.

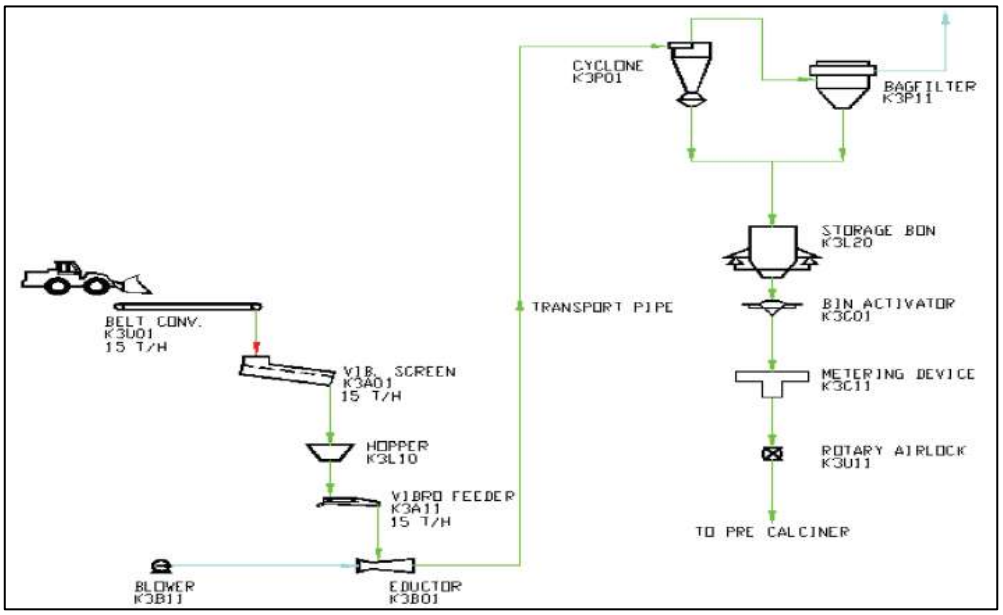
Issues Faced During this Project Implementation

1. Jamming issues were looked because of high dampness content amid blustery seasons. Consequently, it is fitting to keep the dampness content well beneath 1o% preceding it is nourished into the framework.
2. Mud content – the natural mud contained in the bolster tends to diminish the C3S substance of the resultant clinker and was along these lines remunerated by making suitable changes in the crude blend.

(b) Rice Husk as an alternative fuel in cement kiln – Lafarge India Pvt. Ltd., Arasmeta Cement Plant

Project Details

Lafarge India Pvt. ltd has set up an arrangement of terminating Rice Husk as an elective fuel for the Kiln to diminish Coal Consumption. The framework includes a bolstering framework, a passing on framework and an encouraging framework. This is an exceptionally viable method for arranging Risk Husk – an agrarian waste and is accessible in plenitude in our district.



Source: World Cement August 2019

Figure 16: Rice Husk Utilization as fuel in Lafarge Cement Plant

Results of the Project

Utilization of Rice husk substituted 5-8 % of coal utilized as a part of furnace and PC terminating. Diminishment in Co_2 emanation points of interest as Mentioned underneath:

Table 6: Rice Husk Project Results

Actual	629	629	629	607	607	607	576	579	586
Planned	600	600	600	600	600	600	600	600	600
	Without rice husk in 2007						With rice husk in 2009		

Source: CMA Statista 2022

Issues Faced in implementation of the Project

Capacity of high volume of rice husk is an issue as the mass thickness of Rice Husk is less and therefore it possesses a major space for capacity and in this procedure it gets sullied with remote materials and is presented to dampness and along these lines making an issue of stream capacity amid bolstering and terminating. In this way Plant group has made numerous measures for safe stockpiling of rice husk with the goal that it doesn't get sullied.

Environmental effects of Alternative Fuels

It is exceptionally off base to express that consuming of waste inferred fills, for example, TDF does not contain dangerous materials. Burning tires in the open is greatly unsafe to human well-being and condition. The exhaust produced are tainted with a few harmful chemicals that tires contain, for example, unstable natural mixes like benzene, metals, for example, lead, polycyclic sweet-smelling hydrocarbons, for example, benzopyrene, also, manufactured elastic parts, for example, butadiene and styrene. Furthermore, the chlorine content in tires leads to the formation of dioxins and furans that are to a great degree dangerous chemicals, when tires are singed.

The relative natural impacts of consuming tires in cement ovens relies upon the sort of fuel being supplanted and the measure of warmth input gave by the tires. Exploratory examinations have uncovered that up to 3o% substitution by TDF can be securely accomplished. The consuming of tire chips rather than entire tire lessens lethal metals i.e. zinc and chrome. The utilization of tires into a furnace fuel can give a considerable lessening in nitrogen oxide (Nox) discharge while giving a generous sparing in fuel costs. This is an ecological and income agreeable answer for the Nox

diminishment prerequisites. Contingent upon the sulfur substance of powers being supplanted, sulfur dioxide outflows can go down.

Substitution of TDF around 1o-25% for coal in incinerators does not fundamentally modify the concoction substance of the emanations. To legitimize this cases, TDF advocates point to government considers like the Environmental Protection organization's 1997 report "Air Emissions from Scrap Tire Combustion" which expresses that: "In view of the aftereffects of the [EPA rotating furnace incinerator simulator] test program, it can be inferred that, except for zinc discharges, potential emanations from TDF are not anticipated that would be particularly unique in relation to from other traditional petroleum derivatives, as long as burning happens in an all-around planned, very much worked and all around kept up burning gadget."

Be that as it may, in India the utilization of TDF isn't practically speaking due to delays on part of State Pollution Control Boards and the Central Pollution Control Board in giving intrigued plants condition leeway The restrictive cost of the CPCB endorsed tests which keeps running into Rs.o.5 to Rs.o.8 crores for every trial is a noteworthy disadvantage in the utilization of TDF as elective fuel. The costs require for the diverse trials and tests are forced on that individual plant. This is an exorbitant undertaking and a hindrance being used of elective fuel in Indian concrete plants.

Despite the availability of these alternative fuels the total emissions that are reduced are still less and can be further enhances by the use of natural gas. This report deals with the feasibility analysis and cost benefit analysis of replacement of coal who natural gas in the cement industry. But, before we do the above mentioned analysis we need to understand and calculate the amount of coal that is being used in the cement industry in India.

4.15 COAL AS FUEL IN CEMENT INDUSTRY IN INDIA

Coal is the fundamental fuel for the make of concrete in India, given the high cost and insufficient accessibility of oil and gas. The utilization of coal in dry process framework ranges from 20-25per cent of clinker production. That implies 0.20-0.25 T of coal is expended to create one ton of clinker. The concrete business expends around ten million tons of coal yearly. Since coalfields like Bharat Coking Coal Limited (BCCL), Central Coalfields Limited (CCL) supply low quality coal, the industry needs to mix high-review coal with it; imported coal draws in a traditions

obligation. The power area is the biggest purchaser of coal took after by the iron and steel and concrete industry. The present coal utilization is around 6oox1o6 T, out of which around 85x1o6 T is foreign made.

Coal is a kind of flammable carbonaceous shake, with various natural and inorganic constituents, shaped from collected vegetable issue that has been changed by rot and different measures of warmth and weight, more than a great many years. Coal shifts generally in its arrangement. It is made predominantly out of rings of six carbon iotas combined in a greatly complex structure of layered courses of action that have in them, hydrogen as well as huge measures of oxygen and nitrogen. The structure likewise incorporates fluctuating measures of sulfur and other natural toxins. Coal is normally broke down for dampness, unpredictable issue, settled carbon and cinder. The sulfur and nitrogen content are essential, as discharges of their substance oxides amid coal burning contaminate air.

Concrete division (third biggest coal devouring part) accounts for 5% of India's aggregate coal utilization. India is the second biggest maker and purchaser of cement with the concrete creating limit of 36o MT in 2o15. In the previous 1o years, coal utilization by this part has expanded 2.5 times. About two-third of the coal expended in FY 15 was foreign made. It represents 6.7% of the aggregate world creation. India's per capita utilization of concrete as of March 2o15 was 19o kg, which was significantly less than the created and creating economies. Fast urbanization, increment in framework speculation by the Government of India, framework ventures like keen urban areas and devoted cargo hallways, improvement of metro rail activities, modernization and development of air terminals will be the principle factors driving the concrete request. The request is relied upon to achieve 55o– 6oo MTPA by 2o25 from the creation level of 256 MT in FY 2o14 (CAGR of 7– 8%). Considering this development rate, concrete creation in FY 2o2o will be around 389– 4o7 MT. Such a quantum would bring about the coal necessity of 78– 82 MT (expecting utilization standard for G11 coal review: 2o1 kg/T of cement production).

For coal to be used in cement industry there are certain requirements that the coal must fulfill. The requirements the coal must fulfill are as follows:

Table 7: Characteristics Requirement by Cement Industry

Sl. No.	Characteristics	Requirement
i)	Total Moisture content,	Max. 8
	(at 60 percent RH and 40°C) percent by mass	
ii)	Volatile matter, (air dry basis) percent by mass	Min.24
iii)	Ash, percent by mass	
	a)dry Process	Max. 27
	b)Wet process	Max.24
iv)	Sulphur, percent by mass	Max.0.8
v)	Chloride, percent by mass	Max.0.01
vi)	Size, mm	Max.250

Source: World Cement August 2020

Around 25 tons of coal are utilized to make 1oo tons of concrete. Coal shapes around 2o% of the aggregate working expense. The business utilizes around 5% of coal delivered in the nation. Up to this point, private responsibility for mines was not allowed in India and all buys must be produced using government-possessed coal mines.

The legislature and Cement Manufacturers Association (CMA) make designation of coal. The amounts are settled in the wake of making evaluations of likely creation and furthermore in view of past execution of the unit concerned. Units at a more noteworthy separation endure in view of high transport costs and (if there should arise an occurrence of a few units) delays in getting coal on account of extra transshipment time (misfortune in exchanging coal from wide measure to meter check wagons).

Coal is bounteously accessible fundamentally in eastern Madhya Pradesh, Orissa, Bihar, north Andhra Pradesh and eastern Maharashtra. The coal fields are wasteful bringing about deferrals in coal accessibility. Since the nature of coal is poor (high fiery debris content) and conflicting, this prompts issues of value control for bond plants.

Some of the time, in spite of the fact that coal is accessible, rail transport isn't, which powers concrete makers to transport coal utilizing trucks, or buy coal from neighboring customers who have not utilized their coal designation. To conquer these issues, beach front based organizations like Gujarat Ambuja import coal. However absence of sufficient port offices frustrates huge scale import of coal into India.

In February 1996, the mining area was in part changed and bond organizations were permitted to set up hostage coal mines. Up to this point, just ACC has gained a coal square, Lohar in Maharashtra for hostage mining.

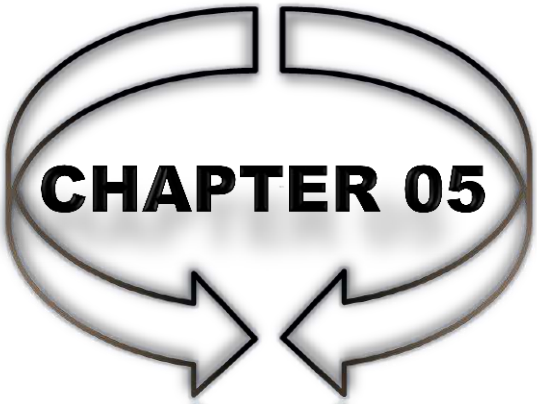
Coal beneficiation is creating as a long haul answer for the business given the continuous weakening in coal quality combined with lacking accessibility. Beneficiation includes setting up of washeries with which the fiery remains substance of the coal can be diminished to the required level expanding the general productivity of the furnaces.

4.16 CONCLUDING REMARKS

As per the above analysis, it is certain that cement industry needs to be shift its production activities towards approaching incessant green and sustainable initiatives. India, being a developing nation is expected to crucially analysis the major initiatives introduced by other countries and build up its own alternatives that best fit to its economic and environmental viability. Notably, among other alternatives, Natural gas energy can be the convenient substitution of fossil fuels, considering its abundance available reserves in India. The other alternative might attract heavy expenses, whereas Natural gas would be better alternative in cutting down the production cost in cement sector of India.

As a clean fuel, natural gas can reduce a small amount of HTP, MAETP, POCP, and EP, compared with the 10% coal-saving scenario. Furthermore, it can also reduce a large amount of AP and terrestrial ecotoxicity potential (TETP) at the same time. In general, natural gas, as an alternative fuel, is much more advantageous than coal-saving in the **Combined Heat and Power** (CHP) plant.

Natural Gas is suggested for the plants located in Rajasthan which are near the natural gas grid are the ones who can gain a lot with a minimal expense. Cement plants located near the gas fields in Andhra Pradesh, Saurashtra, Assam and also the plants in Rajasthan and UP located near the HBJ pipeline can implement this and be a role model for the cement industry in India.



SUMMARY AND CONCLUSION

KEY HIGHLIGHTS

- *Findings of the Study*
- *Findings of Case Study*
- *Hypothesis Testing Result*
- *Recommendation for the Study*
- *Scope for Future Studies*
- *Conclusion*

The data were arranged in a manner that was suitable for the context of the inquiry. The results are based on assumptions made from the data and the researcher's views influenced by observations and discussions with experts. While several of the characteristics collected in the survey had limited empirical significance in the context of this study, the researcher considered them to be significant from a domain viewpoint. Additionally, an appropriate statistical technique was used to evaluate the hypotheses. This chapter analyses the following objectives and hypothesis:

5.1 FINDINGS OF THE STUDY

- The findings of the study revealed that a majority of the respondents are male.
- The outcome from the data analysis revealed that majority of the respondents of the study are middle-aged individuals.
- The results from the data analysis, it has been revealed that majority of the respondents of the study are graduates.
- The analysis from the study revealed that respondents serving in a variety of managerial positions in cement power plants in the state of Rajasthan.
- The results of the exiting study from the data analysis revealed that almost half of the power plants that are a part of the study have the size of 660 Megawatts.
- The findings from the data analysis revealed that 30.2 percent of the cement power plants covered under the study have the installed capacity of 4 X 500 TPH Boilers.
- The results of the study stated that almost half of the cement power plants included in the study has been in operation for 8 years.
- The outcome from the data analysis have revealed that all the cement power plants covered under the study utilise coal as a fuel.
- The findings of the existing study stated that 23.3 percent of the cement power plants considered under the study have a daily fuel requirement of 18,000 Metric tonnes.
- The outcome from the data analysis stated that all of the respondents opine that coal produces lower amounts of energy upon combustion as compared to natural gas.

- The result of the study stated that a majority of the respondents are of the view that natural gas requires lesser quantities of air for combustion as compared to coal.
- The outcome of the research documented that all of the respondents opine that natural gas burns faster as compared to coal.
- The results of the study showed that a majority of the respondents are of the view that the utilization of natural gas as a fuel in the process of cement production does not result in an increase in the quantity of clinker produced as compared to the corresponding quantity of clinker produced in coal-based production of cement.
- The findings of the study stated that a majority of the respondents opine that coal-based production results in the generation of ash that needs to be disposed.
- The results of existing research stated that a majority of the respondents are of the view that coal-based production of cement requires significant quantities of water for the removal of impurities.
- The outcome of the study indicated that a majority of the respondents opine that coal-based production of cement results in the emission of compounds such as CO2 and SO2 which have adverse effects on the environment.
- The findings of the study stated a majority of the respondents are of the view that the process of burning coal does not produce ash that contains Ur and Th at up to 10 times their original levels.
- The results of the study showed a majority of the respondents are of the view that coal-based production of cement requires the application of heavy machinery and technical expertise.
- The findings of the study stated that all of the respondents opine that coal-based captive power plants have a high requirement of water for the removal of impurities.
- The results of the study showed that all of the respondents opine that the fluctuations in the availability and pricing of coal in the international as well as domestic markets lead to continuous challenges for the cement industry.

- The outcome of the study indicated that a majority of the respondents are of the view that the costs associated with power and fuel constitute a significant percentage of the total cost of production incurred in coal-based production of cement. Furthermore, the aforementioned respondents also opine that power and fuel costs consume a fifth of the revenue earned from the production and sale of cement.
- The results of the existing research stated that a majority of the respondents are of the view that the elimination of the process of grinding of coal can lead to significant savings in terms of electrical power per ton of cement produced if natural gas is used instead.
- The outcome of the study indicated that all of the respondents opine that the utilization of natural gas as fuel in the production of cement instead of coal can lead to savings in terms of lower fuel cost and lower handling costs.
- The results of the study showed that a majority of the respondents are opine that coal-based cement power plants cause significantly greater damage to the environment as compared to the power plants that utilise natural gas as fuel.
- The outcome of the study indicated that a majority of the respondents are of the view that significant investments in terms of capital cost are required to shift captive power plants to natural gas-based power plants.
- The results of the study showed that a majority of the respondents opine that coal-based production of cement leads to the creation of a toxic sulphur-based compound that causes widespread water pollution.
- The results of the study showed that all of the respondents are of the view that the utilization of coal as fuel in the production of cement causes several health hazards and has an adverse impact on the environment.
- The outcome of the study indicated that a majority of the respondents opine that coal-based production of cement pollutes water bodies, including lakes, rivers, and streams. Furthermore, the aforementioned respondents are of the view that the use of coal as fuel in cement production causes contamination in the supply of drinking water in the state of Rajasthan.

- A majority of the respondents are of the view that the patterns of activity displayed by the wildlife in Rajasthan are changing quickly and continuously owing to climate change related factors.
- The results of the study showed that a majority of the respondents opine that the burning of coal results in the production of higher quantities of greenhouses gases as compared to other fossil fuels, thereby causing an adverse impact on the environment.
- The outcome of the study indicated that a majority of the respondents opine that owing to the lack of adequate and timely supply of coal, the operations and the efficiency of their cement power plants are adversely affected.
- The outcome of the study indicated that all of the respondents are of the view that the long distances between the coal mines and the captive power plants lead to bottlenecks in the movement and stocking of coal, thereby hampering the efficiency of the operations of the power plants.
- The results of the study showed that all of the respondents opine that it is difficult to manage the planning and execution of inbound and outbound logistics in the case of coal-based captive power plants.
- The outcome of the study indicated that all of the respondents are of the view that coal-based power plants lead to the production of several harmful substances, including Carbon dioxide and Mercury, that have an adverse impact on the health of the people working in those plants.
- The outcome of the study indicated that all of the respondents opine that avoiding the process of burning coal can lead to substantial savings in terms of healthcare costs. Since the emission of harmful pollutants by coal-based power plants leads to diseases such as asthma and cardiac issues, avoiding the burning of coal can lead to a reduction in the occurrence of said diseases.
- The outcome of the study indicated that all of the respondents opine that the lack of proximity of coal-based power plants with the suppliers of coal and relevant markets adversely affects the total volume of sales and the per unit cost of coal.

- The results of the study showed that all of the respondents are of the view that it is challenging to maintain the quality standards of coal over the course of its supply throughout the year.
- The outcome of the study indicated that all of the respondents opine that there is a higher feasibility for the achievement of full capacity utilization and capacity enhancement in natural gas-based power plants as compared to coal-based power plants.
- The results of the study showed that all of the respondents are of the view that the concept of cement power plants that utilise various forms of energy as fuel, including coal, solar, and wind energy, is useful in saving the cost associated with the cross-subsidy charges levied by different states on the inter-state sale of electricity. Furthermore, the aforementioned respondents opine that the application of such power plants is a threat to electricity distribution companies because it affects their total revenue.
- The results of the study showed that for "Supply / logistic issues" and "Emerging Issues" in using coal as a fuel in captive power plant in cement industry, respondents from 660 MW size of plant found more agreed as compared to others with mean value of 4.65 and 4.75 respectively.
- The outcome of the study indicated that for "Supply / logistic issues" and "Emerging Issues" in using coal as a fuel in captive power plant in cement industry, respondents from 3960 MW installed capacity of plant found more agreed as compared to others with mean value of 4.73 and 4.80 respectively.
- The results of the study showed that for "Supply / logistic issues" and "Emerging Issues" in using coal as a fuel in captive power plant in cement industry, respondents from plant with 2 years of age found more agreed as compared to others with mean value of 4.56 and 4.70 respectively.

5.2 FINDINGS OF CASE STUDY

- The results of the study showed that the recent trend in North America has depicted a wide adoption of renewable alternatives plant mechanism for meeting the industrial needs of energy consumption. the Natural gas - fired plants have outreached the phenomenal significance to the energy consuming industries such as paper, cement, tire etc. as the best short-term energy replacement of coal.

- Studies revealed that during past years' natural gas prices have seen a major decline over coal due to the advancement of Shale gas techniques. the coal prices depict the double of the natural gas prices nearly $US 0.02 kilowatt/hour, leading to additional labor and housekeeping expenses. therefore, turning from conventional to non- conventional energy sources were a convenient choice for the cement industry. The results of the study showed that
- The outcome of the study indicated that many natural gas plants are still far beyond the reach of many cement manufacturers, causing higher plantation cost and many safety hazards such as flame distinction, flame flash back, automatic flame valve shut off, and extinction of natural gas. These issues are temporary and can be mitigated through a proper training & safety mechanism.
- The results of the study showed that Natural gas and coal combustion process requires different flame intensity. The natural gas can be heated at 100^0C less than Coal combustion.
- The facts & findings revealed in the study would unknot the major aspects, assisting cement manufacturers, scholars, and other contributories in the relative field.
- The outcome of the study indicated that considering the main three countries under NAFTA "The Mexico, U.S, and Canada" have been the greatest contributories of cement production and consumption.
- The outcome of the research indicated that the cement industry has witnessed the phenomenal upsurge of energy consumption during the past years. As the cement process, particularly the calcination of raw materials in kiln captures the highest amount of energy for fuel burning. As a result of which, the cost of production had become the greatest concerns for the cement manufacturers of North America.
- The cement industries in Canada and Mexico seemed to be more efficient. On the other hand, the emerging environment sustainability regulations, GHGs emissions restrictions, consumer awareness heightened the prevailing concerns of the region.

- The outcome of the study indicated that to shorten the demand supply gap and ensuring uninterrupted production the U.S. and Mexico shifted from wet to dry kiln technology for being more energy efficient and less pollutant operational system.
- The results of the study showed that The US Toxics Release Inventory (TRI) reported that "the cement industry is the fourth-largest emitter of dioxins and furans, and accounts for about nine percent of all air emissions".
- The outcome of the study indicated that EPA clearly demonstrates that Industrial process, accounting 65% of total GHGs emission, have been the prime contributories among other sectors over the last decade. The increased production and switch from fuel oil to petroleum coke were among the major arguments of the humongous release of GHGs, causing ruinous impact on biodiversity, and ecological environment.
- The outcome of the research indicated that the cement industries in U.S. applied sophisticated measures to kiln flamed hazardous waste, expected to lessen the dioxin release by approx. 40%.
- The outcome of the study indicated that the cement kiln dust as one of the major by-products of cement, was the greatest concerns for the environmental regulatory.
- Natural Gas while comparing the physical and chemical properties with the solid fuels reflected impeccable satisfactory results. The study attempts to enlighten the crucial findings, highlighting economic and environmental properties between coal and natural gas exploring various dimensions of combustion, the kiln adjustment, and calcination etc.
- The results of the study showed that the chemical properties of Natural Gas are such that it contains high carbon and hydrogen content, causing the high calorific value but lower carbon to hydrogen proportion makes it emitting lessor CO2 than coal for the same material input.
- The outcome of the study indicated that considering the mass combustion capacity of 3000 t/day calciner kiln with the energy injection of 260MW, generally the products rang in natural gas remains less. Through reducing the volumetric air flow of O2 by 4% to 1.5% while existing calciner the per day clinker production capacity can significantly be increased by 5% to 10% as

compared to the coal. Further, in addition to the capacity expansion the grinding cost can be optimized by adopting the natural gas.

- The outcome of the research indicated that considering the shortfall, some raw material adjustment is required in natural gas processing. Moreover, the cement quality further can be improved mixing gypsum at the grinding stage.
- The outcome of the study indicated that a detailed understanding of various heat transfer scenarios such as "counter flowing, coflowing streams, and residence time variance" is required while switching from coal to natural gas combustion process.
- The results of the study showed that natural gas burning is attainable by gearing up the thermal substitution rate (TSR) up to 30% and thereby required a minimal burner adjustment.
- The outcome of the research indicated that natural gas plant observation in North America demonstrates that in the short residence time of 1.5 seconds, the exit temperature in case of 100% natural gas burning slightly hiked as compared to the conventional coal.
- The outcome of the research indicated that the coal fired kiln and calciner process is possible to be replaced with highly intensive natural gas substitution even with negligible detrimental effects.
- The outcome of the research indicated that Natural gas firing would be benefiting in countering the deposits build up and SO3 cycle problems, which in coal combustion add up bulky GHGs emission due to incomplete burnout till the kiln exit.
- The results of the study showed that Calciner with shorter residence time or with lack of O2 adversely affects the coal burning intensity due to incomplete combustion, not evident in natural gas fired plant.
- The outcome of the study indicated that the combustion optimization in natural gas system further leads to production increase by 5 to 10%, lower fuel consumption, energy cost savings by lowering handling and grinding cost, and reduced dust losses.

- Studies revealed that due to the absence of practicality environmental regulations "the cement industry has until now allowed cement manufacturers significant freedom in their choice of fuels and pollution control equipment".
- The results of the study showed that Cement kilns burning hazardous wastes should be regulated as hazardous waste disposal facilities.
- The outcome of the research indicated that Energy efficiency standards and greenhouse emission standards for the cement sector should be adopted in all three countries.
- The outcome of the study indicated that the CEC should initiate a dialogue about the burning of alternative wastes in cement kilns with a specific focus on dioxin and furan emissions and the control of CKD.
- The outcome of the study indicated that the CEC should continue to strengthen its Sound Management of Chemicals program to emphasize a North American Management Strategy of hazardous wastes and reduction of dioxin and clinker emissions.
- The reports also found that the emission standards for hazardous chemicals in Canada, introduced by CCPE in 1999 have yet to be implemented.
- Studies found that the type of fuel used by cement facilities in North America regions, is highly ascertained by their price and availability rather than the energy efficiency or sustainability motives. Nonetheless, the consolidation impact of cement industries in U.S. and Mexico, on the shift to natural gas-fired plant is subject to new insights in future studies.
- The results of the study showed that in Nigeria, the non- conventional alternatives such as biomass, fuel oil, natural gas etc. are emerging as the better alternatives for coal -fired power plants in terms of physio-chemical properties, GHGs emissions, cost and availability etc
- The outcome of the study indicated that the trend is evolving much rapidly than before, particularly in the industries worldwide. As a result, "Between 2011 and 2019, 121 coal-fired units in the US were considered to burn other types of fuel, according to the US Energy Information Administration (EIA)".
- The outcome of the study reveals that except Spent Carbon Lining (SCL), Industrial lubricants, and tires and Natural gas combustion, others were found

to have more CO2 emitting intensity even greater than coal. Also, they require heavy feeding meal requirement, attracting excessive cost.

- The outcome of the research indicated that Portland cement is most widely used across the world due to its prominent quality. The manufacturing of Portland cement can be processed either through dry process or wet process. However, the modern industries are preferably adopting the dry process production due to the advantages of energy saving and clean air emittance.
- The results of the study showed that in Cement manufacturing, the total energy is diversified as 1.9 % for raw grinding, 92.7% for clinker production, and 5.4 % for finish grinding. The amount of energy can be saved by switching fuel alternatives, depending upon their calorific value and physio-chemical characteristic. Hence, the type of fuel determines the GHG emission, cost and energy saving, and product quality.
- The outcome of the study indicated that Natural gas as having the highest calorific value (54.0 MJ/Kg) while coal stands at the lowest (36.3 MJ/Kg).
- The outcome of the research indicated that among three fuels, coal is found as the most abundant fossil fuel on the earth and contributes the highest (41%) of world's electricity generation. While fuel oil is extracted from petroleum distillation.
- The outcome of the study indicated that in terms of cement kilning heat production, fuel is regarded as "heavy fuel oil, or low pour fuel oil (LPFO)" where heavy fuel is used to "produce electricity, to fire boiler and furnace in industry, notable the cement, pulp, and paper, and to power large marine and other vessels.
- The results of the study showed that oxygen and water content is higher in natural gas while it comprises lessor CO2 level than coal and oil.
- The outcome of the study indicated that petroleum oil is the most expensive and highly threatening to flora and fauna lives. Although, it is readily available to Nigerian cement industry but considering the apparent peril to the environment, the Government has put across consumption restrictions over it.
- The studies show that natural gas is the cheapest energy source and due to its easy availability in Nigeria, it has been the first choice for cement companies.

- The results of the study showed that reason of declining trend of coal energy consumption in Nigeria is due to shutting down the coal mines by Government orders.
- The study indicates that observing the future expedition of environment sustainability, the cement companies in Nigeria are now much into exploring better alternatives, though expecting lower final production cost through energy saving techniques.
- The outcome of the study indicated that the critical investigation of different alternative fuels considering their physio- chemical properties, feeding material requirement, and combustion emission, and cost effectiveness entail different impact on cement production.
- The outcome of the study indicated that many cement producers have considered Natural Gas as the best replacement of coal and oil due to its higher favourable characteristics concerning the cost and environment.
- The outcome of the study indicated that environmentalists regarded Natural Gas as the temporary energy solution due to its limited availability in future. Also, many experts opine that natural gas is nowhere counter off the GHGs effects of coal combustion as Methane, the most hazardous in GHGs amounts around 33% emission.
- The outcome of the study indicated that price and availability has played a significant role in determining the fuel adoption in Nigerian cement sector.
- The outcome of the study indicated that showed that the cheaper price and easy availability have promoted the Natural gas adoption in Nigeria over the past time.
- The outcome of the study indicated that The U.S. has also been witnessed Coal as the largest energy producer in the country. According to a report, in the U.S., approx. Coal produced 38% of the total power generation. Due to being widely available with a relatively lower cost of energy production.
- The outcome of the study indicated that in the United States, coal power plants typically produced energy through different generating units. The pulverized Coal is obtained through crushing and grinding, which is then sieved and dried with heated air.

- The outcome of the study indicated that the cement industry of the U.S. stood at third among the world's largest cement producers for over past decades. The U.S. cement industry was noted 3.4% of global CO2 emission in 2001.
- A research article reveals that "Global carbon dioxide (CO2) emissions" from the cement industry consisted of "approximately 829 million metric tons of CO2 (MMTCO2) in 2001.
- A study reveals that "In 1975, dry kilns comprised 38% of all kilns, whereas, in 2001, dry kilns accounted for approximately 70% of all kilns". Surprisingly, the overall cement production of the U.S. increased from 75 MMT to 90 MMT over the same period.
- A statistical report reveals that as Compared to the energy consumption of 6.3 million Btu per short ton in the wet process, the dry process observed only "5.5 MBtu/st".
- A study reveals that energy consumption increased much faster due to the robust demand for cement in the construction industry.
- The outcome of the research indicated that Coal was the highly used substance among all, consumed at cement kilns, approximately 71% in 2001.
- The results of the study showed that since the U.S. witnessed an overwhelmed demand for energy in the cement industry, mainly sourced through Coal, the heavy and incessant Consumption of Coal turned into a matter of concern for the entire industrial sector, majorly depending on it.
- The outcome of the research indicated that according to EIA, "approximately 73% of U.S. coal-fired power plants aged over 30 years or older at the end of 2010" while the normal average life time of CFPPs remains 35 to 50.
- The outcome of the research indicated that the combustion-related Co2 emission in the industry increased by 17% from 1994 to 2001.
- A study reveals that In the United States, approx. 4-5% emission is found in masonry cement, which, after adding with gypsum, turns into Portland cement.
- The outcome of the research indicated that China completely relied upon coal power plants as the prime energy source, which increased its coal plants

capacity five times from 2000 to 2019 and is now consciously employing new renewable energy resources.

- The results of the study showed that China has planned to reach the carbon-neutral stage by 2060 to replace Coal-fired power plants with other alternatives.
- The outcome of the research indicated that biomass combustion significantly reduces the emission of hazardous substances including "sulphur nitrogen oxides, and mercury".
- Studies reveal that mitigation of pollutants through Biomass technology would require many decades to replenish the harvested trees.
- The results of the study showed that due to excessive woods cutting, greatly threatens wildlife conservation, biodiversity, and water supplies.
- A study reveals that in June 2010, the environmental officials of Massachusetts states reported a 3% hike in carbon emission from biomass-fired energy by the year 2050. Consequently, the Gadsden plant had been burning biomass which by the end of 2011-stopped biomass energy generation.
- The outcome of the research indicated that In U.S. the idea of conversion from subcritical to supercritical upgradation could never be implemented in practice due to excessive cost burden and ambiguous concept clarity.
- Recent studies in the U.S. mainly focused on GHGs emissions and the relative cost & performance efficiency improvement in the Cement industry.
- A study reveals that burning natural gas generates 45 % less carbon than Coal and a minimal quantity of nitrogen oxides, sulfur, and mercury.
- A study reveals that natural gas could only be seen as a short-term solution to set off the Coal produced environmental impacts till the full development of wind, solar, and geothermal resources.
- The outcome of the research indicated that U.S. coal power plants were converted into natural gas plants as the gas plants were more economical, clean and matched the clean air standards released by the EPA.
- The results of the study showed that the Consumption of energy using different fuel resources from the year 1971 to 1997.

- The outcome of the research indicated that by the year 1997, Coal has been the most consumed resource for the energy requirement of the cement industry, whereas the use of natural gas had drastically fallen over the time.
- A study reveals that the total emission in the U.S. has declined from 3600 MtCO2e/year to 2600 MtCO2/year from 2002 to 2018.
- The outcome of the research indicated that the gradual reduction in coal power generation, which by 2018 ranges only between 1000- 2000 Twh/year. In contrast of which, Natural gas observed the highest energy production ranging between 1700 to 2700 TWh/year during the study period.
- The outcome of the research indicated that Carbon Competitiveness Incentive Regulation" (CCIR) set a new common baseline for the generators of 'combined-cycle natural gas plants. As per the scheme objectives, the coal electricity producer pays more, whereas the cleaner energy facilities would be awarded under the scheme.
- The results of the study showed that due to exhibiting enormous benefits such as clean air, sustainable environment, less carbon emittance, these natural resources have observed an upsurge trend in total generation over the past years.
- A study reveals that renewable fossil fuels emission has been strictly underlined by U.S. Government, which in case of non-implementation are legally penalized by the concerned authority.
- The outcome of the research indicated that Different types of fuel release diverse chemical substances that can deteriorate the required chemistry of the cement components and the overall operational system.
- The study found that only the natural gas alternative has been seen as the most prominent replacement of coal plants, as it comparatively found to emit 45% less carbon emission.
- The outcome of the research indicated that high prices, biodiversity loss, ambiguous concept clarity, less acceptability, and mare short term outcomes are some of the challenges before the U.S. Government in pervasive implementation of Natural gas energy implantation.

- The outcome of the research indicated that 8% of the global carbon emission, causing a threat to the socio-economic serenity. Considering the issue, "Global Cement and Concrete Association (GCCA)", demonstrating 30% of the cement production capacity worldwide has announced the industry's first "Sustainability Guidelines".
- A study reveals that Germany-based Heidelberg Cement in Norway has initiated a waste based alternative fuel resources as a replacement of coal energy.
- The results of the study showed that being the 3rd largest producer of coal in the world, the production-based carbon emission in India has heightened from 500 million tons to 2.5 million tons (1990-2019).
- The outcome of the research indicated that the Indian cement sector is one of the highest energy intensive industries, depicting (15.60%) of total coal fuel consumption.
- A study reveals that in 1950 Japan' s energy consumption need was majorly depended on coal, one third hydroelectricity and rest on oil.
- The outcome of the research indicated that by 2001, the contribution of natural gas has increased to 50.2% of the total with a rise in the use of nuclear and oil fuels.
- The outcome of the research indicated that the coal energy use declined to 24.3% in 2017 from 50% in 1950 whereas, natural gas use got a hike of 24.6% over the same period and now being used as the prime energy source for the cement sector of Japan.
- The results of the study showed that the overall transformational journey of cement industry in Japan, focusing on the major challenges, and initiatives in terms of alternative fuels energy adoption.
- A study reveals that 75% of energy need in Japanese cement plant was channelized through fossil fuels and remaining 25% from electric energy. Surprisingly, some decades ago, coal accounted for 92% out of total energy requirement and rest part from oil fuel and high-speed diesel in cement manufacturing in Japan.

- The outcome of the research indicated that Japanese Cement Association (JCA) have propounded many advanced clean coal technologies (CCTs), and other alternative energy resources. Some researches demonstrated the process wise energy use in cement plants of Japan and found Pyro-processing as one of the most coal energy consuming stages.
- A study reveals that among all stages, pre -calcination and pyro-processing consume both electric and coal energy, accounting for 93% of total fuel consumption.
- The outcome of the research indicated that Limestone contains about 75- 90% CaCO3 in raw form which after processing through primary and secondary crushers are converted into 25mm size. Generally, the mining and quarrying process mostly consume electric energy and high-speed diesel and oil fuel.
- The results of the study showed that the choice between ball mill or VRM depends upon various factors including moisture content of the raw material, the size of the plant, the abrasiveness of the material, the energy consumption levels, reliability, and economic viability.
- The outcome of the research indicated that despite having the greatest environmental threats, coal energy covers around 90% of the global energy consumption requirement.
- The outcome of the research indicated that the analysis of the major cement companies in Japan demonstrates the fact that it takes about 200-450kg coal energy to produce 1t of cement.
- A study reveals that Japan had been facing the coal scarcity and been the third largest importer (188 Mt) in 2014 after China and India, which made it extremely expensive for the cement sector.
- these kilns were found to be far more energy efficient and enabled mass production, which cut down the coal energy use by about 40% as compared to the wet process.
- The results of the study showed that the kiln capacity of SP and NSP kilns were increased by 3.3 times and 4.9 times respectively than the older process.

- The outcome of the research indicated that electric power by on-site power generation including power generated by waste heat recovery (WHR) covers more than 60% of the total electricity consumption in cement sector of Japan.
- A study reveals that Palm kernel shells (PKS)", currently being one of the cheapest biomass energy products in cement sector of Japan.
- Studies suggest that the LNG is expected to remain for longer than the oil fuel and illuminating as the prime energy source for the future.
- The outcome of the research indicated that the share of natural gas in Japan as the primary energy supply depicts the third largest global contributor after U.S.A. and Europe.
- The results of the study showed that U.K. is exhibiting more than 50% of oil and natural gas in energy efficiency, whereas, Japan comes up at third position (around 45%) of gas cover, which is higher than its coal energy efficiency output.
- A study reveals that India stands at fifth rank, depicting the higher natural gas energy efficiency than coal. In a nutshell, the above analysis demonstrates a strong picture of Japan in terms of Natural gas energy viability.
- The outcome of the research indicated that it is clear from the above graph that Japan is the 4th largest player (65%) after Russia, UK, and France, concerning the share of natural gas out of total electricity of fossil fuels.
- The results of the study showed that Natural gas has been considered as the primary alternative of coal energy due to its numerous chemical and cost related attributes.
- The outcome of the research indicated that a comparative analysis of top cement companies in Japan illustrated that those, who primarily used natural gas as a replacement of coal, have been exhibiting lower carbon combustion, medium calorific value and lower moisture content, despite having old kilns and other technologies.
- A study reveals that the shift from coal to gas brought up as one of the most viable cement industries of Japan as the renewable fuel (natural gas) comprehensively supported the adoption of new dry kilns technologies.

- The outcome of the research indicated that major part of CO2 emission (more than 50%) was observed at calcination stage where limestone is converted into lime ("CaCO3 → CaO + CO2") and about 40% of the CO2 emission was due to burning coal of high calorific value.
- The results of the study showed that the cement companies witnessed an overall decline in a production cost from 30% to 50% over the last 5 years.
- A study reveals that the increasing use of electric energy in waste material substitution as alternative fuel have reduced the CO2 content and the demand of natural gas in the cement sector as well.
- A study reveals that the preheating stage about 40% to 60% fossil fuel was burned followed by the calcination of raw mix.
- A study reveals that to achieve higher thermal efficiency and optimal production and cost, Natural gas has shown up as the most popular fuel for cement production.
- The results of the study showed that the new green energy efficiency technologies (SP, NP preheaters, Dry process making) have not only improved the kiln quality but cut down the total production cost, comprising major part of energy use cost.
- The results of the study showed that the adoption of NG is being considered as the most prominent fuel, observing the future trends.
- The outcome of the research indicated that release of excessive methane and scattered availability are still the factors of higher cost and pollution in some countries.

5.3 HYPOTHESIS TESTING RESULT

Hypothesis Result		
S. No.	**Statement of Hypothesis**	**Results of Hypothesis testing**
1	H01: Technical and Commercial respondents do not differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry.	Ho Rejected

2	Ha1: Technical and Commercial respondents differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry.	Ha Accepted
3	H02: Respondents from different plant age groups do not differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry.	Ho Rejected
4	Ha2: Respondents from different plant age groups do differ significantly in explaining various issues for usage of coal as a fuel in captive power plant in cement industry.	Ha Accepted

5.4 RECOMMENDATION FOR THE STUDY

- Power plants, coal mines, and other energy sources have a direct influence on the cement market, the environment, and human health. Compared to coal and fuel oil, natural gas is a more affordable and ecologically benign energy source that is readily accessible in many nations. The following recommendations are made: reduce energy costs, provide power supply to the power plant, and decrease the emission of hazards to the environment generated by the cement industry (cement manufacturing).
- The cement businesses in Rajasthan should make a concerted effort to attain meaningful levels of energy efficiency, and this should be one of their top goals.
- When compared to fuel oil, coal is less expensive, and it is expected to provide a significant portion of the fuel used in cement manufacturing. Rajasthan businesses are moving toward the usage of alternative and traditional fuels in order to minimise environmental pollution.

5.5 SCOPE FOR FUTURE STUDIES

- Present research restricted to Rajasthan. As a result, future research may include other geographic sites for a more thorough examination.
- Future research should find more energy sources that may assist cement businesses in lowering their cost of production, such as solar energy used as a fuel source for raw materials and finished items in the cement industry.

- Future research might include a comparison of the different fuels utilised by developing and industrialised nations to produce cement products.

5.6 CONCLUSION

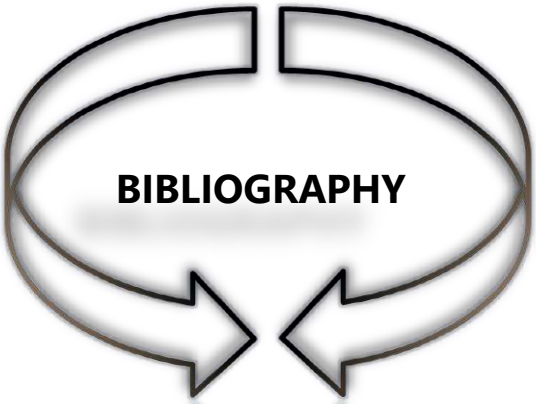
Cement manufacturing is a high-energy intensive business. Substituting alternative fuels for some conventional fuels provides both economic and ecological benefits. From a technical and environmental standpoint, the cement industry is well adapted to the usage of such fuels. Alternative fuels are used in a large number of cement manufacturers globally. Numerous cement plants in other nations currently utilise natural gas as an alternative fuel source. Cement manufacture is a highly energised process. Numerous researchers reported energy costs as accounting for between 30% and 40% of the total cost of cement manufacture in their study articles. Another statistic is that the cement industry consumes around 2% or almost 5% of the world's primary energy. At the moment, coal and coke are the primary fuels used in Indian cement factories. Recent years have seen a minor growth in the use of waste fuels, particularly tyre-derived fuels (TDF). Globally, the number of TDF facilities is increasing significantly.

This study delves further into the practises of many foreign nations with regard to alternative fuels, particularly natural gas used in cement making. It focuses on the types of alternative combustibles used, their environmental and economic advantages, their impact on concrete production and quality, and the challenges associated with shifting from conventional to alternative fuels.

This previous research sought to conduct an empirical examination of alternative fuels, most notably natural gas. It will be a valuable source of information for cement firms interested in using natural gas as an alternative fuel source in India and Rajasthan.

The cement industry's manufacturing efforts must be redirected toward perpetual green and sustainable projects. India, as a developing country, is required to critically analyse big international projects and create its own alternatives that are economically and environmentally viable. Notably, given India's abundant natural gas reserves, natural gas energy may be a practical substitute for fossil fuels. The other option may incur significant costs, but natural gas is a more cost-effective way to reduce production costs in India's cement business.

Additionally, it has the ability to significantly diminish both AP and terrestrial ecotoxicity potential (TETP) at the same time. In general, natural gas is a significantly more favourable alternative fuel than coal in a combined heat and power (CHP) plant. Natural gas is recommended for facilities situated in Rajasthan that are close to the natural gas infrastructure since they may earn a lot with a little investment. Cement facilities situated near gas resources in Andhra Pradesh, Saurashtra, and Assam, as well as plants located near the HBJ pipeline in Rajasthan and Uttar Pradesh, may execute this and serve as a role model for the cement sector in India.



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Questionnaire

Questionnaire for Industry Leaders/Production Managers

Dear valued Respondent,

I am conducting "**A Study on Feasibility of Rajasthan Cement Industries Power Plant on Usage of Natural Gas as Clean Fuel in Comparison of Coal"** as a part of my Ph.D Progamme. Your help in completing this questionnaire is much appreciated. Please be assured that all your responses are confidential and will not be lead to in any way. Your personal information will not be given to any other organization and will only be used for the purpose of this research only.

Section-A - PERSONAL DATA: Demographic Factors

Please put your response by a tick (√) mark

1. Name(Optional)_____
2. Gender:

   a. Male □ b. Female □
3. Designation: _____
4. Age:_____
5. Education:_____
6. Size of Plant:_____
7. Installed capacity of the plant:_____
8. Age of the plant:_____
9. Specify Type of Fuel used in your cement production plant and fuel requirement per day also.

Type of Fuel	Consumption per day
o Coal	
o Petroleum Coke	
o Natural gas	
o Gasoline	
o LPG	
o Tire derived fuel	
o west solvents	
o Others	

Section B: Rate your opinion for the following issues related to uses of coal as a fuel in captive power plant in cement industry

S. No	Statement	SD	D	N	A	SA
Technical issue						
1	The calorific value of coal is lesser than natural gas.	1	2	3	4	5
2	The stoichiometric air requirements of natural gas are greater than coal.	1	2	3	4	5
3	Natural gas mixes with the air and burns quickly as compared to coal.	1	2	3	4	5
4	An increase in clinker production can be achieved by firing natural gas as compared to coal.	1	2	3	4	5
5	Coal based production Leaves behind ash requires disposal	1	2	3	4	5
6	Significant water is needed to remove impurities in coal based production	1	2	3	4	5
7	Emission of CO2, SO2, NOX, mercury compounds in coal based production is higher.	1	2	3	4	5
8	Coal contains minor amounts of the radioactive elements, uranium and thorium. When coal is burnt, the fly ash contains uranium and thorium "at up to 10 times their original levels.	1	2	3	4	5

9	Coal based captive power plants requires heavy machinery and maintenance with technical expertise.	1	2	3	4	5
10	Coal based captive power plants requires more water to get rid of impurities.	1	2	3	4	5
	Cost Issues					
11	The continuous volatility in fuel prices in international markets, a probable ban on the usage of petroleum coke, and the uncertainty over availability of domestic and linkage coal continue to post challenges for the cement industry.	1	2	3	4	5
12	Power and Fuel costs in Cement Industry account for more than 50% of the Cost of production and around 20% of Revenue.	1	2	3	4	5
13	Elimination of coal grinding can save electric power/ton cement if natural gas used	1	2	3	4	5
14	In addition to the potential for higher clinker production and the falling price of natural gas energy, further benefits of firing natural gas are the savings on handling costs.	1	2	3	4	5
15	Cost of environmental damages from coal plants is higher as compare to natural gas.	1	2	3	4	5
16	Higher Capital Cost Adjustment for Size and Time is required to shift captive power plants based on natural gas.	1	2	3	4	5
Environmental Regulatory Issues						
17	As coal, fuel contains sulfur and when it mixes with air it makes a toxic substance responsible for pollution in many lakes and rivers.	1	2	3	4	5
18	Air pollution from coal-fired power plants is linked with asthma, cancer, heart and lung ailments, neurological problems, acid rain, global warming, and other severe environmental and public health impacts.	1	2	3	4	5

19	Lakes, rivers, streams, and drinking water supplies are all heavily impacted by coal based power plants in Rajasthan.	1	2	3	4	5
20	Wildlife activity in the Rajasthan is changing dangerously, as conditions become hotter and drier due to climate change.	1	2	3	4	5
21	Coal combustion produces more greenhouse gases than the combustion of any other fossil fuel consequently affect environment badly.	1	2	3	4	5
Supply/ logistic Issues						
22	Lack of adequate coal supply within the time frame of your cement plant is a challenge.	1	2	3	4	5
23	Stocking coal is always a challenge since coal mines are too distant from the captive power plants.	1	2	3	4	5
24	Inbound and outbound logistics and logistics planning is difficult in case of coal based captive power plants.	1	2	3	4	5
Emerging Issues						
25	Coal-fired plants emit not only carbon dioxide; There are also other toxins that have an immediate and direct impact on people's health such as mercury.	1	2	3	4	5
26	Avoiding coal burning would save hundreds million $ a year in health- care costs by avoiding illnesses caused by pollutants, such as asthma attacks, heart attacks and deaths linked to the coal-fired plants' emissions.	1	2	3	4	5
27	Proximity to suppliers of coal and Markets is a challenge and affects sales volume and price per unit.	1	2	3	4	5
28	Maintaining the quality standards of coal during the supply throughout the year is a challenge.	1	2	3	4	5
29	Capacity utilization and increasing plant capacity both are more feasible with natural gas based captive	1	2	3	4	5

	power plants and compare to coal.					
30	Group captive power plants based on coal, solar and wind are operational in large numbers in cement industry of Rajasthan state. The concept was evolved by industries to avoid the cross-subsidy charges levied on inter-state electricity sale and is seen as a threat to state discoms.	1	2	3	4	5

Ques. Give some suitable suggestions to improvise the contribution of Interactive marketing.

Ans. ……

Data Collection Proof

With the reference of the questionnaire for my study I converted the questionnaire into Google form due to the basic reason of COVID 19 Pandamic in which officials did not allow to visit personally. The questionnaire link below mentioned:

https://forms.office.com/r/FVqU6ejT0V

The Google form questionnaire sent to 1000 professionals. With their telephonic conversation I received only 387 filled data which is my primary data sample size. The data collected link below mentioned from which I converted it into excel sheet and used for my analysis.

https://forms.office.com/Pages/AnalysisPage.aspx?AnalyzerToken=zHj4dUwa6X6hlxP88Kkhg1EbITJbsGA9&id=DQSIkWdsW0yxEjajBLZtrQAAAAAAAAAAAAN__gHjynRUQldPVkE0QjhEQTBKRUpVWTRUMzlXUDFFOC4u