RESOURCE OPTIMISATION & SUSTAINABILITY IN CEMENT PLANT

Summer Research Project submitted to

Ultratech Cement Works

Bachelor of Technology

in

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BACKGROUND OF THE WORK:

Sustainability in cement plants has its roots in the growing worldwide awareness about environmental challenges, resource depletion, and the need for sustainable development. The cement industry, which is well-known for having a substantial environmental impact, has increasingly recognised the significance of implementing sustainable practices to mitigate these consequences and contribute to a more sustainable future.

Environmental Impact: Cement production poses substantial environmental issues, including high CO2 emissions, air pollution, water usage, and waste generation. The contribution of industry to climate change and resource depletion has driven the need for long-term remedies.

It is all about the goals of sustainability. They are:

1. No poverty	9. Industry innovation and infrastructure
2. Zero Hunger	10. Reduce inequality within & among countries
3. Good health & well being	11. Sustainable cities and communities
4. Quality Education	12. Responsible consumption & production
5. Gender Equality	13. Climate Action
6. Clean Water & Sanitization	14. Life Below water
7. Affordable & clean energy	15. Life on land
8. Decent Work & economic Growth	16. Partnership for the goals

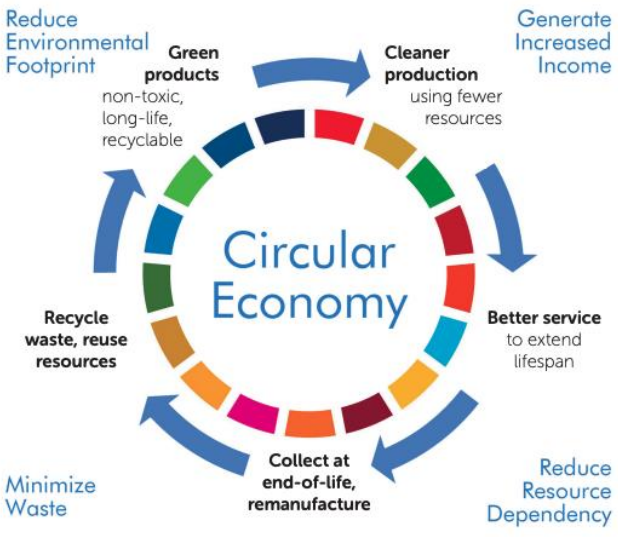


Fig-01 : Sustainability in industry sector [1]

In industries, sustainability refers to practices that combine economic growth with social responsibility and environmental stewardship. It entails incorporating environmentally friendly, socially responsible, and financially viable solutions into the operations and decision-making processes of diverse industries.

MOTIVATION BEHIND THE WORK:

a. Environmental Protection: The urge to protect and maintain the environment is a major motivator for sustainability. Concerns about climate change, deforestation, pollution, biodiversity loss, and resource depletion have emphasised the importance of implementing sustainable practices that reduce negative consequences on the planet while promoting its long-term health and viability.
b. Scarcity and Efficiency of Resources: The growing global population and changing consumption habits have put a strain on finite resources. Sustainable development seeks to maximise resource utilisation, promote circular economy concepts, and reduce waste output. The efficient use of resources such as energy, water, and raw materials helps to minimise resource scarcity and ensures the availability of these resources for future generations.

Let us now discuss the inspiration for this project. When it comes to this generation, saving resources and the environment is always a priority. We can use the money we save for a variety of activities depending on the resources we save. It will also benefit the stakeholders. We can put this money to good use by assisting employees and the environment.

LITERATURE SURVEY:

Sustainability is critical to the well-being of our planet, the continuing progress of a civilization, and human development.Environmental challenges related with GHGs, in addition to natural resource issues, will play a key part in the cement and concrete industry's long-term development over this century.Large amounts of byproduct materials are often disposed of in landfills. By-product disposal expenses are quickly increasing as a result of tougher environmental restrictions. Recycling and developing sustainable construction designs not only contribute to lower disposal costs, but also to the conservation of natural resources. This conservation has both technological and economic benefits.

Several techniques for mitigating sustainable manufacturing in the cement sector have recently been assessed in the open literature, and scientific progress has been made. Carbon capture and storage (CCS), material substitution, the use of alternative fuels, and the use of energy-efficient technologies have all been recommended as ways to reduce the negative environmental impact of cement production.Eco-friendly low-emission cements sometimes struggle to meet performance requirements and satisfy funding evaluators, therefore fully commercialising these innovations remains a difficult undertaking.

The cement sector contributes significantly to India's manufacturing economy, and these are prestigious international venues. While cement consumption is expected to expand, the cement sector will need to minimise CO2 emissions. As the world's largest CO2 emitter, the cement sector is anticipated to make a significant contribution to reducing global GHG emissions in order to keep global warming below 2 degrees Celsius by 2100. Despite the tremendous challenges that the cement industry faces, the research clearly shows that the necessary steps are being taken to transition the business to a low-carbon future. All components of the cement and concrete price must be compatible, and all components of the cement and concrete price must be included in the forces.

Different combination cooling, heating, and power (CCHP) systems are described and examined in this study for waste heat recovery from a cement plant in Sanliurfa, Turkey, with a focus on domestic applications.The cement industry is one of the most energy-intensive industries, wasting over 40% of total input energy.

This is about the carbon capture process, not about its storage. It is only captured, not stored or transported to another location. This document was frequently used in other parts for a basic explanation of carbon capture and storage. Some elements may be very inexpensive to create when the cement factory is first built, but complex or expensive to change subsequently. For example, if some or all of the major pipe-runs for the capture plant are placed concurrently with those for the cement plant, fewer alterations are likely to be necessary later, and a shorter shut-down may be conceivable.

In the transition to a decarbonized society, the construction of a carbon recycling system in the cement industry employing mineral carbonation, such as the MCC&U technology, would contribute to global carbon neutrality. A fundamental calculation of GHG inventory and equations for LCA analysis are described, as well as a decrease of process-related CO2 emissions during cement manufacture, with a focus on a newly proposed calculation for MCC&U.

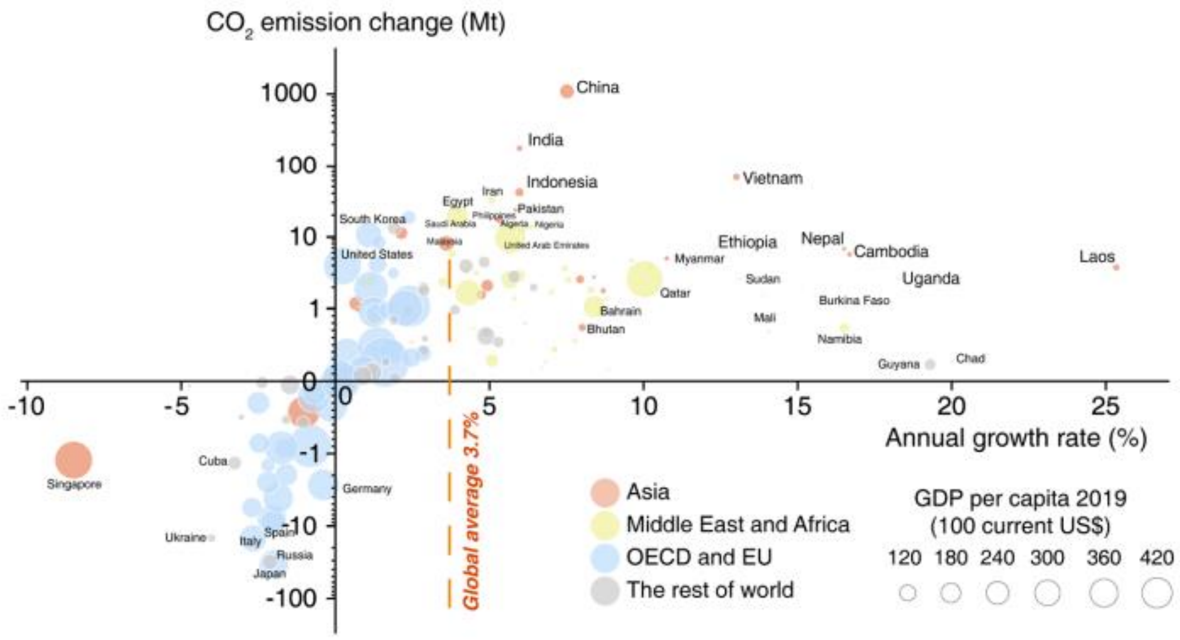
OBJECTIVES:

To improve the sustainability of the cement plant by implementing innovative practices & technologies that minimise environmental impact & promote resource efficiency.

a. to maximise the use of an industrial by-product.
b. Optimised cooling process
c. Carbon capture and storage technology for GHG reduction.

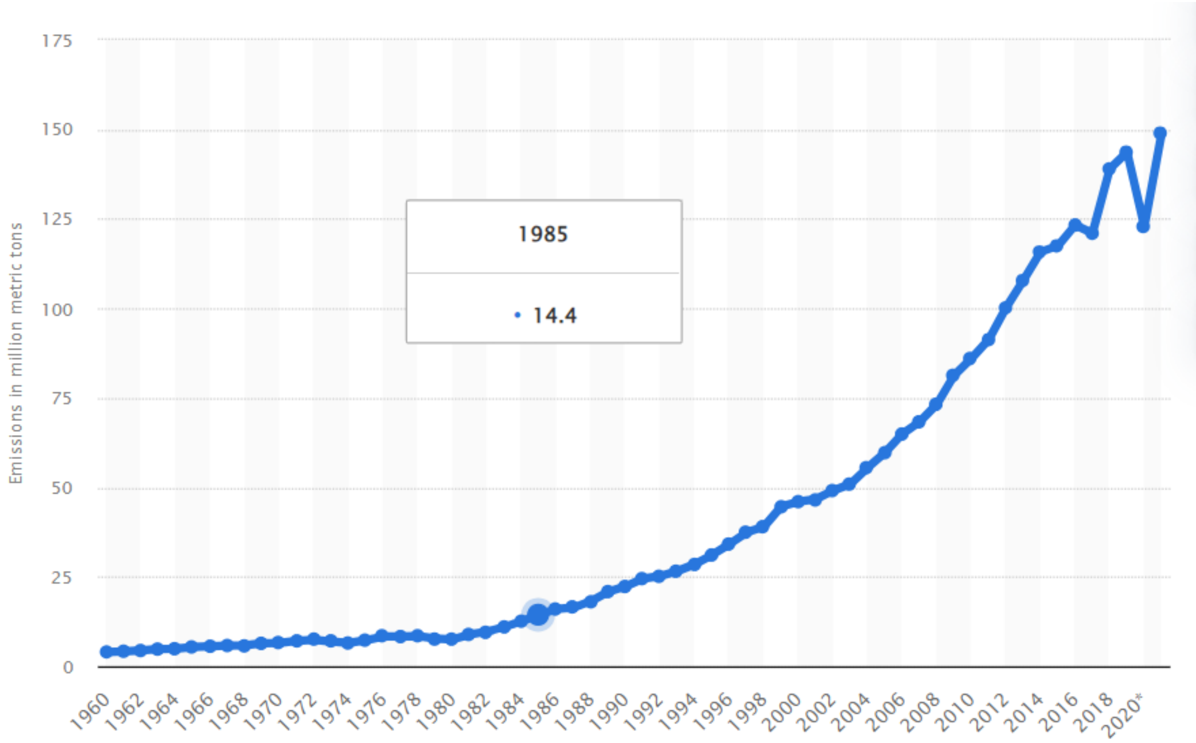
PRELIMINARY SURVEY:

As previously said, sustainability is dependent on a variety of things. But with this project, we're going to focus on one of the world's most pressing challenges right now: CO2. And cement factories are the source of the most CO2 emissions.



CO2 emission change[9]

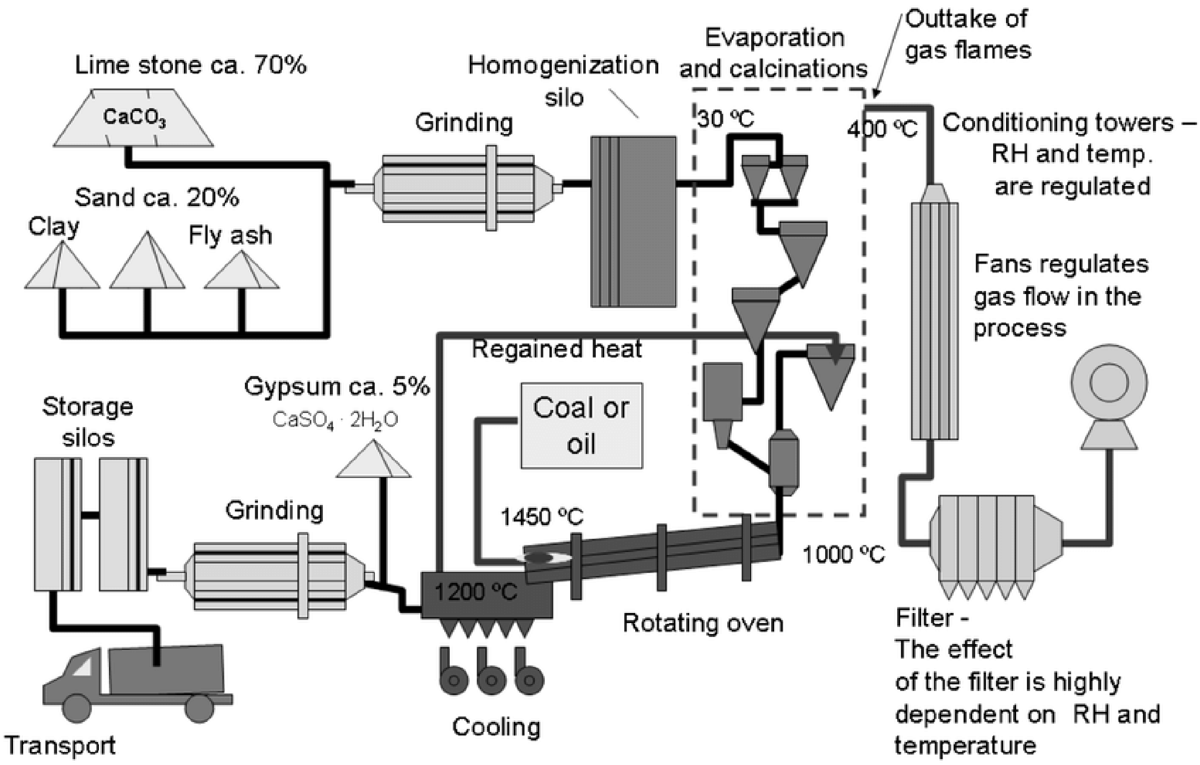
This graph compares national CO2 emissions to annual average emission growth rates from 1990 to 2019. CO2 emissions and growth rates differ by several orders of magnitude, yet similar emission or growth characteristics are also seen. As a result, these countries are divided into four representative regions (Asia, the Middle East and Africa, and the rest of the world) based on their geographic locations, CO2 emission changes and growth rates, socioeconomic representativeness, and contribution to emissions. Asia is mostly dominated by countries with high CO_2 emissions and/or strong development rates.



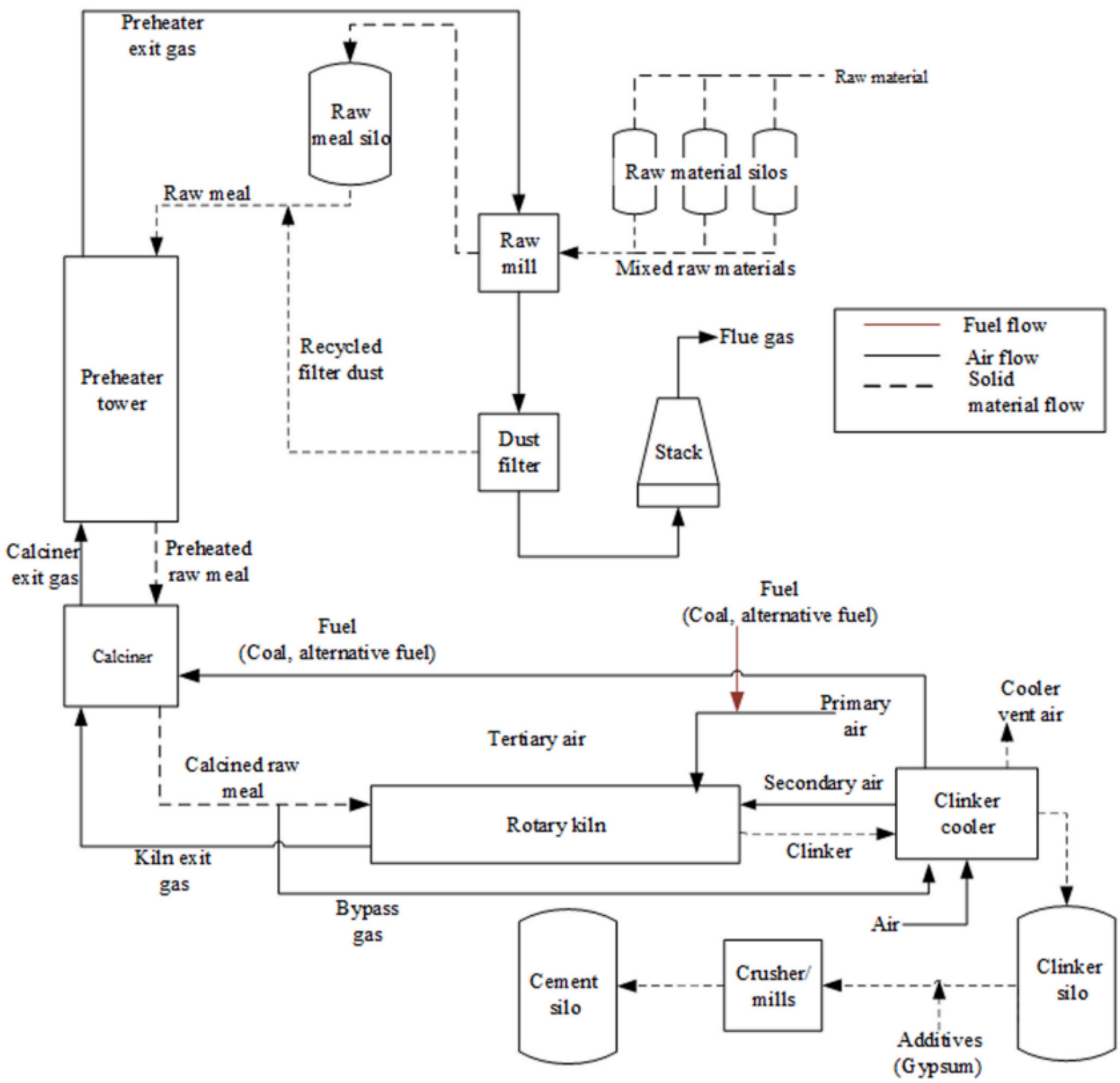
Carbon emissions in india. [8]

As shown in the graph, carbon emissions have increased in tandem with production over the years. Figures hit a peak of 149 million metric tonnes of carbon dioxide ($MtCO_2$) in 2021. The world is already taking action by attempting to eliminate carbon emissions by 2050. Emissions are increasing year after year, and we must be more cautious.

India is the second-largest producer of cement in the world, with about 328,000 tonnes in 2018 (OEA(Office of Economic Advisor), 2019). The 47% of India's cement production covered by WBCSD's(World Business Council for Sustainable Development) data used a clinker ratio of 0.70 in 2014.



Cement manufacturing process[10]



Process flow sheet of a cement plant

The cement manufacturing process is depicted in this flow chart. WE shall concentrate on the area where the largest carbon emissions occur. That section will be covered in the next section. The calcination of the lime ore produces the majority of the co2 emissions.

Compound name	Contents (%)				
	Lime sludge	Clay	Sponge iron	Fly ash	Silico-manganese slag
SiO_2	0.69	43.6	26.64	54.89	28.42
Al_2O_3	0	12.29	14.45	27.54	9.22
Fe_2O_3	0.27	9.49	20.94	5.88	2.32
CaO	96.66	27.89	7.27	0.85	22.34
TiO_2	0	1.07	2.07	2.14	1.59
K_2O	0.32	1.47	1.98	3.95	13.15
MgO	0.77	1.78	1.73	0.87	3.75
P_2O_5	0.63	0.46	1.09	0.45	0.14
Na_2O	0	0	0	1.72	13.21
SO_3	0.22	0.93	3.35	0.54	1.21
SrO	0.07	0.06	0.12	0.01	0.39
MnO	0.02	0.1	0.18	0.02	3.5
ZnO	0.01	0.29	0.85	0.02	0.1
Cl^-	0.22	0.24	1.26	0.21	0.29
ZrO_2	0	0.06	0.14	0.08	0.03
LOI	0.11	0.21	17.89	0.76	0.31

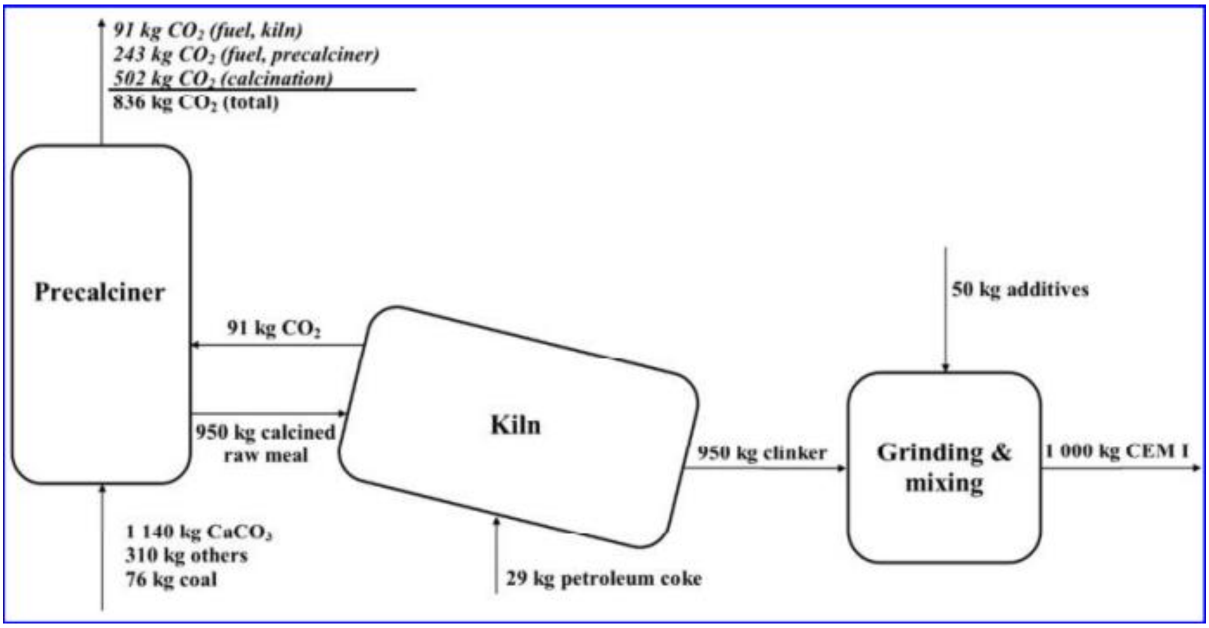
Oxide composition of the industrial waste

METHODOLOGY:

In this section, we will talk about how we can attain plant sustainability. In this project, we considered four options, but there are plenty others. They are

1. Carbon capture and storage
2. Portland composite cement (PCC)
3. Industrial by-product usage

Carbon capture and storage .,

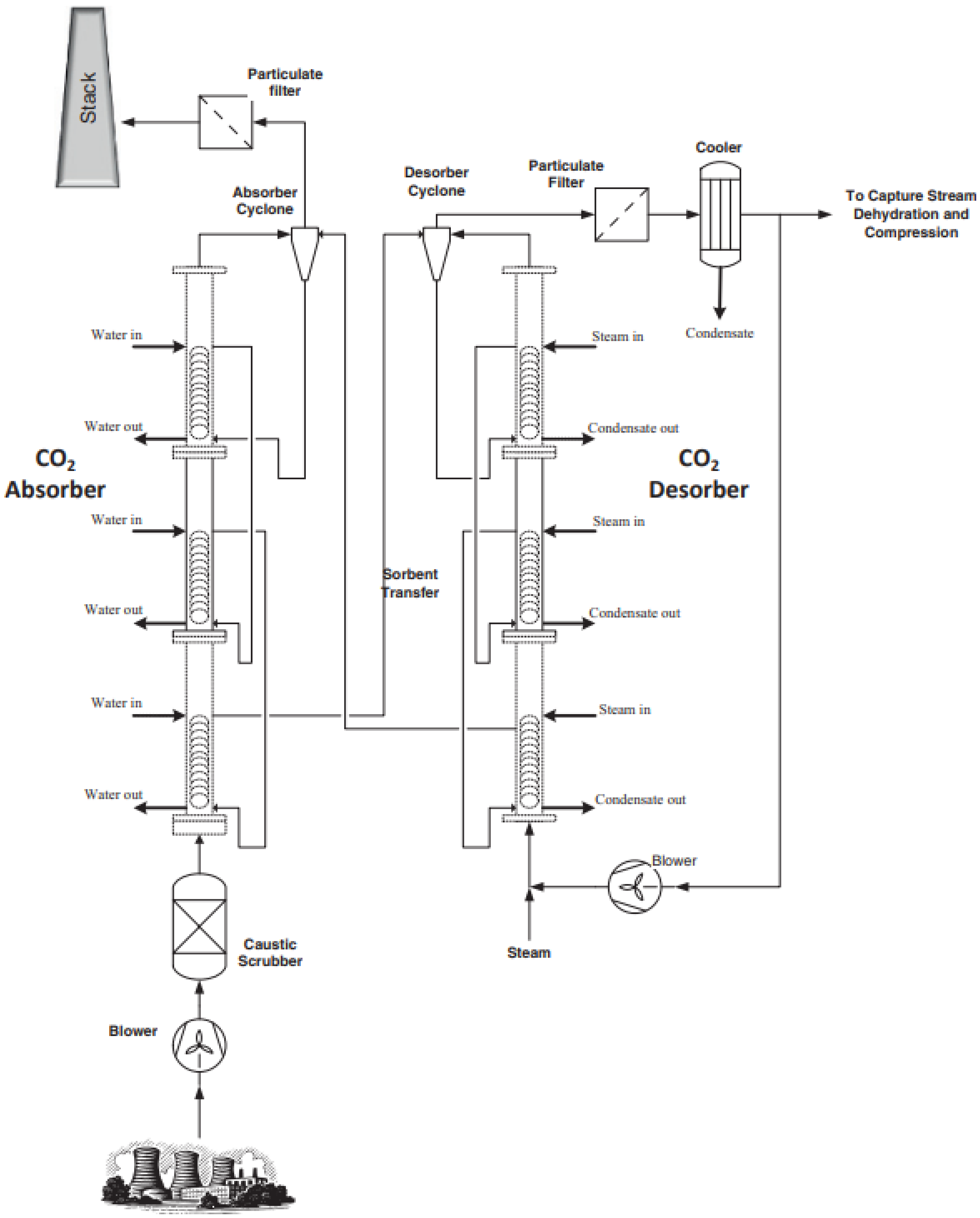


Average Carbon emission.

Unlike other industrial processes, nearly two-thirds (64%) of CO_2 emissions from the Portland cement industry are caused by process chemistry rather than fuel combustion. The other 1/3 generally comes from the combustion of fossil fuels to obtain the heat required for the limestone decomposition process ($CaCO_3 \rightarrow CaO + CO_2$). As indicated in Figure , a typical (1 Mtpa, 3000 tpd) cement plant producing CEM I (95% clinker) emits approximately 880 kg CO_2 per tonne of clinker. However, increased clinker substitution, alternative fuel use, and thermal energy efficiency can only lead to a reduction in specific emissions per tonne of cement from 730 kg CO_2/t cement in 2009 to around 540 - 590 kg CO_2/t cement in 2050.

Amine scrubbing, calcium looping, full oxy-fuel combustion, partial oxy-fuel combustion, and direct capture are the five promising carbon capture techniques. If there was a strong incentive to commercialise cement CCS as soon as feasible, amine cleaning would most likely be the first option.Direct Capture and Calcium Looping appear to be making the most progress and may achieve (Technology Readiness Level)TRL 7 by 2020.

Solid, sorbent-based technologies are one promising method of CO_2 capture. Solid sorbents are regarded as promising since they have high CO_2 loadings, low heat capacities, are often less corrosive, and do not induce toxicity (when reacting with CO_2).The procedure is being developed as a less expensive alternative to traditional aqueous amine CO_2 cleaning. The sorbent material is composed of branching polymer chains with a high density of amine groups and is based on CO_2 -philic poly amine (PEI).



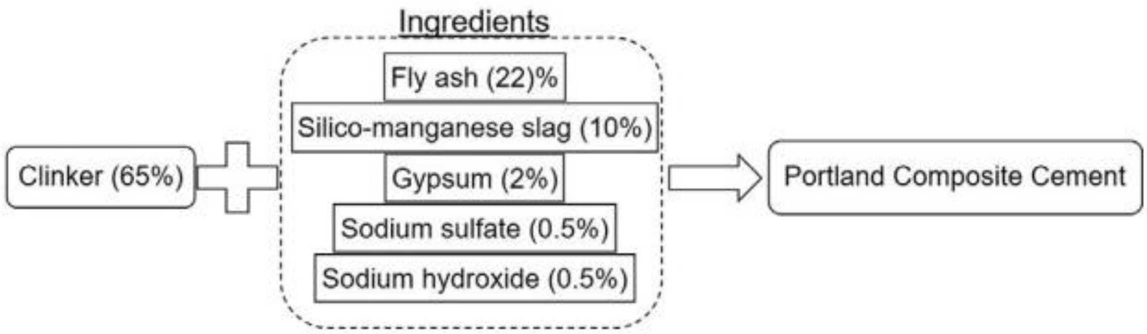
Advanced solid sorbent CO2 capture process. [12]

The caustic scrubbing system removes the strong acids (SO2, HCl) from CO2 heavy flue gas entering the capture system boundaries from a coal plant. Flue gas enters the CO2 absorber and comes into contact with lean sorbent, which selectively eliminates CO2 and generates heat. Water cooling is used to manage the heat. To remove adsorbed CO2, the CO2 rich sorbent is indirectly heated with condensing steam. The sorbent is then returned to the absorber for further CO2 removal.

Portland Composite Cement .,

A large-scale vertical kiln is used for clinkering. The unburnt carbon present in the sponge iron is used as an energy source for calcining the raw materials reducing the demand on external fuel. **A Portland Composite Cement (PCC) is produced by inter-grinding the clinker with waste generated by the pharmaceutical industry, silico-manganese slag and fly ash.**

OPC is the traditional name for cement made by inter grinding clinker with gypsum. OPC is composed of 90-95% clinker by mass, with a gypsum concentration ranging from 0 to 5%.Furthermore, PCC is made by combining or inter-grinding clinker with additional cementitious materials. The clinker element of PCC ranges between 30 to 80%, while the composite portion is made up of additional cementitious materials such as fly ash, slag, limestone, and silica fume.Clinker composition is typically 45% in ultratech Portland composite cement practises. The fly ash content is 25%, and the silico-manganese ash content is 30%. These are the basic values.



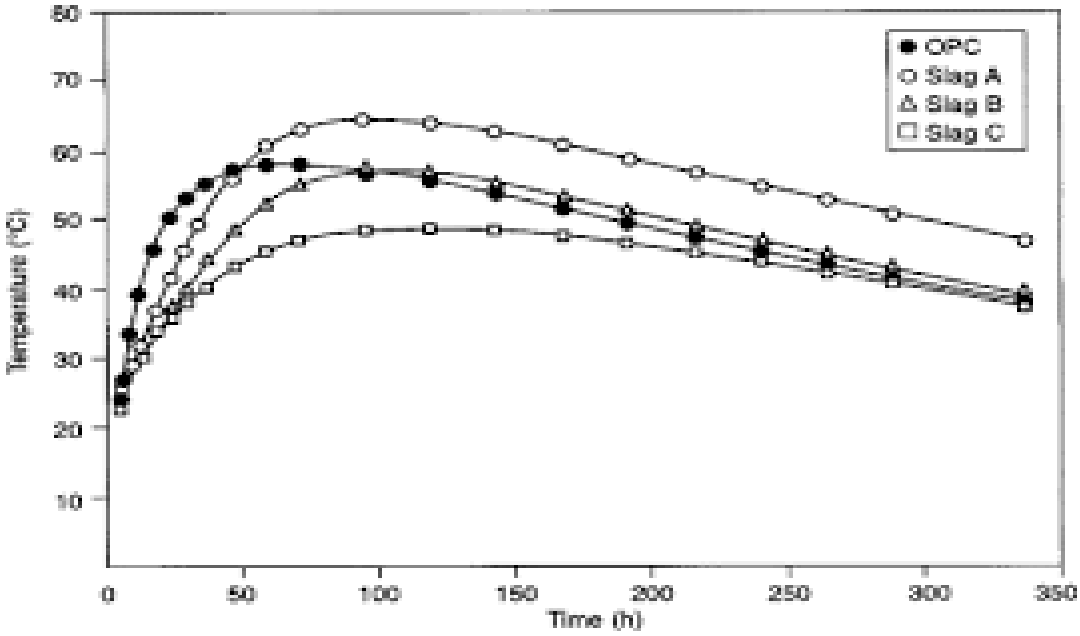
Schematic representation of the PCC production

Compound name	Clinker	PCC	OPC-43
SiO_2	13.64	22.06	22.37
Al_2O_3	4.39	9.11	5.98
Fe_2O_3	5.99	5.58	3.81
CaO	67.45	52.69	62.77
TiO_2	0.40	0.79	0.39
K_2O	1.00	1.24	0.70
MgO	1.00	0.96	1.44
P_2O_5	0.73	0.85	0.19
SO_3	3.24	4.11	1.97
SrO	0.04	0.04	0.03
MnO	0.03	0.15	0.15
ZnO	0.89	0.79	0.00
Na_2O	0.88	1.09	0.19
Cl^-	0.27	0.49	0.00
ZrO_2	0.02	0.03	0.00
CuO	0.02	0.02	0.00

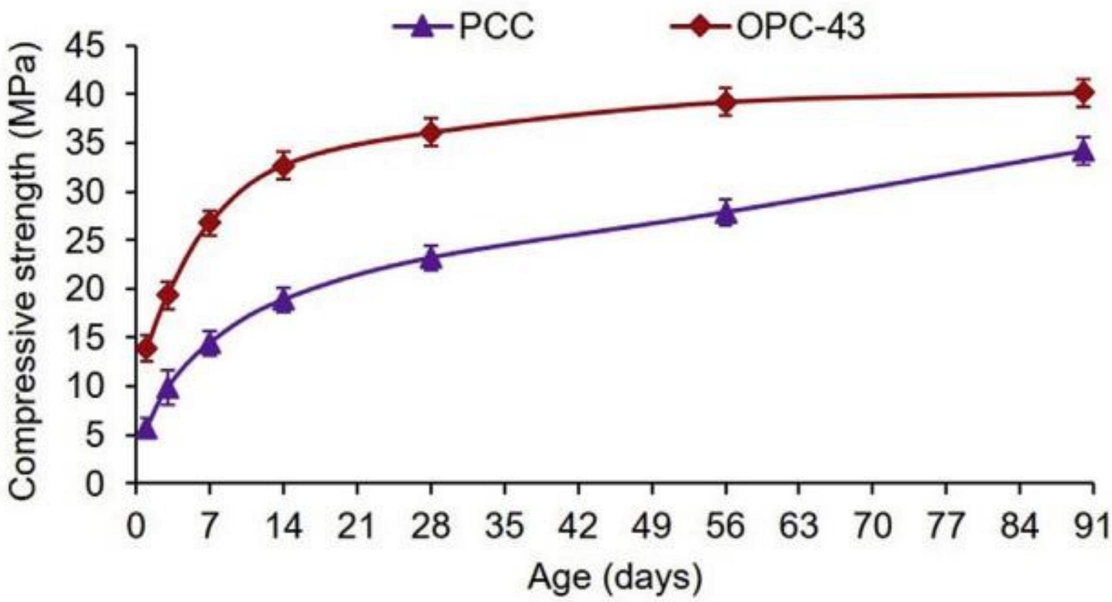
Oxide composition of clinker, PCC, OPC

The reactive calcium and reactive iron levels were calculated by subtracting the crystalline forms of calcium and iron, such as calcite, hematite, and magnetite, from the total calcium and iron oxide contents. In the PCC, there is a reduction in the calcium content and an increase in the alumina content when compared to the clinker.

When the oxide composition of PCC and clinker were compared, identical components were present in both systems with varying levels. The Al2O3 and SiO2 concentrations of PCC were higher, with a minor decrease in CaO content.



Composite Cement - overview [11]



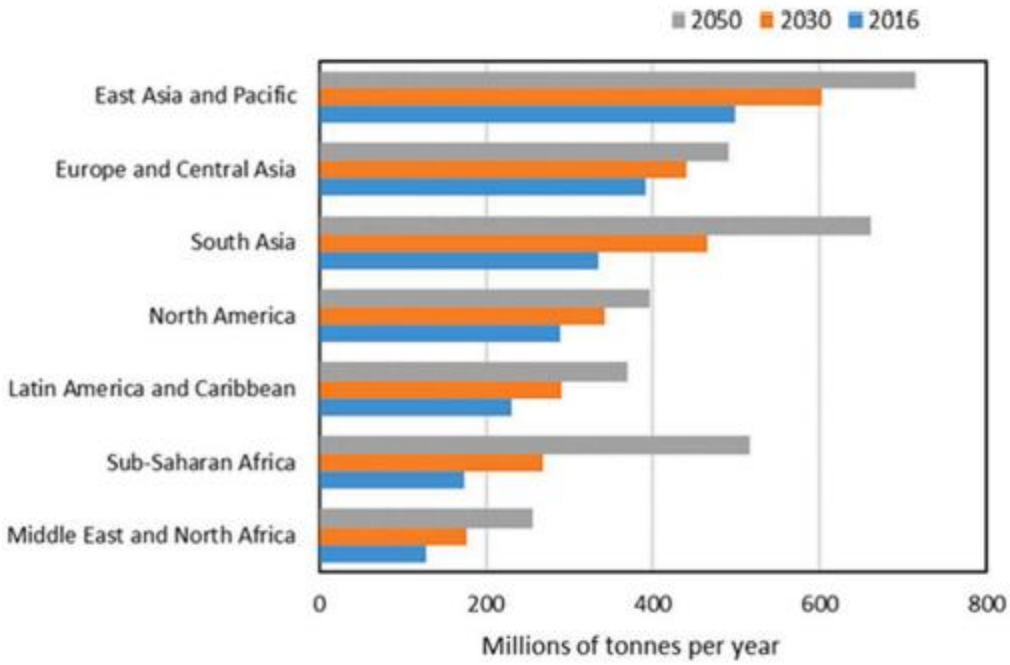
Compressive strength of PCC and OPC in 90 days duration

Clinker and PCC both exhibit a sustained improvement in strength for up to 90 days. When compared to clinker, the PCC shows a considerable rise between 28 and 90 days.The initial rate of strength growth in PCC concrete was slower than in OPC concrete.

A belite-rich hydraulic clinker is made using a large scale pilot kiln and many post industrial waste materials such as lime sludge waste, sponge iron, and low-grade clay. The viability of making a low-heat composite cement with silico-manganese slag, fly ash, and pharmaceutical waste is demonstrated. The proposed methodology will result in the effective use of post-industrial waste materials in cement manufacture, hence reducing the CO2 footprint and energy usage. The unburned carbon in the sponge iron reduced the external energy requirement in the clinkering process during the manufacturing process.The use of lime sludge waste as a source of calcium is demonstrated, which would help reduce the consumption of natural limestone.

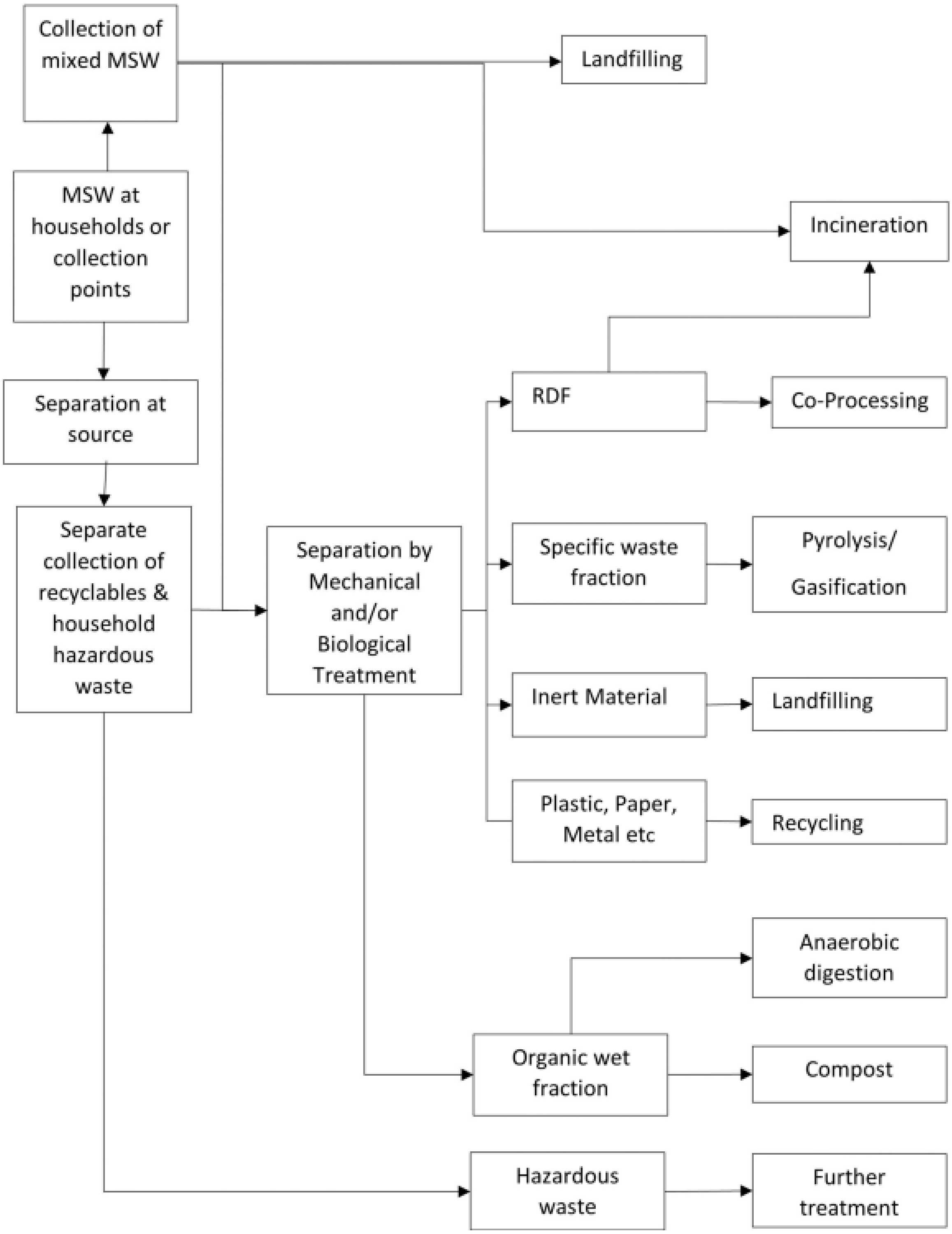
Alternative Fuel System .,

Co-processing refers to the use of waste products as a partial replacement for traditional fuels and/or raw materials in manufacturing processes in order to recover energy and/or resources.Waste co-processing at cement plants now significantly contributes to the promotion of industrial symbiosis under the umbrella of the circular economy by giving a unique opportunity for energy recovery and waste management.Figure illustrates a comparison of garbage generation in 2016, classified by region of the world, as well as waste forecasts for 2030 and 2050 in each region. In 2016, Asia, the Pacific, and Europe were the top three garbage generators, and they will be among the top four in the next thirty years.



Project Municipal Solid Waste generated by region [13]

Alternative fuels are any material or substance that can be used as a fuel other than fossil fuels (petroleum oil, coal, and natural gas). They are also known as non-conventional and advanced fuels. Biodiesel, bio-alcohol, waste-derived fuels, hydrogen, non-fossil methane, non-fossil natural gas, vegetable oil, and other biomass sources are some well-known alternative fuels. These fuels have been used in a variety of energy-producing activities, including transportation, electricity generation, and industrial machine operation.MSW collected as "mixed waste" or "separated waste at the collection point" is handled mechanically, biologically, or chemically to recover valuable materials.



Overview of MSW material overflow.

Cement kiln and precalciner as destinations of SRF:

Using (solid resource fuel)SRF in cement kilns and precalciners is a good solution for both waste producers, who are under pressure to find a proper final destination for their produced material, and cement plant operators, who want a good production economy, optimal production energy allocation, and minimal environmental impacts.Potential waste feeding locations for dry kilns are

i) the main burner at the rotary kiln outlet end,

ii) a feed chute at the transition chamber at the rotary kiln inlet end (for lumpy fuels),

iii) a separate burner in the riser duct between the kiln inlet and the precalciner,

iv) a feed chute in the precalciner (for lumpy fuels)

v) a separate precalciner burner.

Secondary fuel co-processing, such as SRF, provides economic, social, and industrial benefits. To attract end-user applications, SRF manufacturing and use must be economically, socially, and technically feasible. Because of the high-temperature, energy-intensive processes that occur in such systems, a cement factory is an appropriate destination for SRF. Co-processing in cement kilns/precalciners effectively uses the material and energy value of wastes, preserving natural resources by decreasing the need of virgin material.

FINAL OUTCOME/CONCLUSION:

These are only a few of the numerous steps we may take to achieve sustainability. We discussed carbon capture and storage, Portland composite cement, and alternating fuel in this project. Carbon capture and storage offer a lot of potential for preserving sustainability in cement plants in the future.

Carbon dioxide emissions are increasing, as we all know, and this is not benefiting global sustainability. When compared to ordinary cement, the Portland composite cement uses fewer raw ingredients. In general, composite cement uses between 45 percent of clinker. They also play an important role in conserving raw materials for the alternative fuel system. These are the methods for preserving sustainability in a cement plant.

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