QATAR UNIVERSITY

COLLEGE OF ENGINEERING

LIFE CYCLE SUSTAINABILITY ASSESSMENT OF AGGREGATE RECYCLING FOR NEW CONSTRUCTION: THE CASE FOR QATAR

BY

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ABSTRACT

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Title: LIFE CYCLE SUSTAINBILITY ASSESSMENT OF RECYCLED AGGREGATES FOR NEW CONSTRUCTION : THE CASE FOR QATAR

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The purpose of this project is analyze the use of recycled waste material management for the purpose of circular economy concept, in addition to adopting the concept of life cycle assessment in order to use it for quantifying the benefits and impacts of construction waste recycling the LCA assessment methodology will be used which consists of goal and scope identification, inventory analysis and impact analysis, the scope of this project is focusing on the base foundation of stadium in Qatar, inventory analysis and impact analysis are dealing with the quantities of both conventional and cyclopean concrete and their impacts of environment and society. There is a comparison of using recycled aggregates such as Cyclopean concrete in construction projects and the Conventional Concrete where a calculation will be done to evaluate both systems based on concrete amounts while taking into consideration the unit price of concrete, steel reinforcement and fuel. the main focus will be on sustainable assessment and using of recycled materials in constructing mainly focusing on aggregate for new construction projects in stadium's base foundation. There will be a comparison to measure the advantages of using recycled material in aggregates versus the conventional concrete from environmental and social indicators with around 9 indicators in total , the highlights of using recycled materials helps in; Reduced resource use , material

re-use on site , preventing unnecessary transport emission , minimizing waste generation and dust suppression & control. Based on the project recommendation will be provided for more sustainable construction method, where Cyclopean concrete has less impacts of the indicators taken into considerations on the surroundings.

DEDICATION

This project is dedicated to my family for their continuous love and support, without them believing in me I would not be able to do it. Hopefully I've made them proud of me.

I appreciate their continuous help.

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I would like at first to thank my master project supervisor Dr. Murat Kucukvar in Qatar University for his continuous support during the whole project, he was always delighted to help at any time whenever I needed him. Dr. Murat is consistently supporting this project to be done in the best way it can be while adopting different techniques and analyses in Engineering Management program.

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CHAPTER 1 : BACKGROUND

With the blooming of many infrastructure project, which aims to serve the rapid development of Urban, the construction projects have been found beneficiary. In addition to the increase of sustainable development awareness in near countries, many actions especially proactive actions from governments and professional companies attempt to acknowledge and introduce the concept of sustainability. This paper shows the current application of sustainability aspects in Qatar with many ongoing projects and the impact on the environmental changes along with the importance of sustainable applications in regards to construction projects. An aggregate recycling introduction has been receiving more attention, where recycled aggregates come from doing a reprocess on the previously used in construction for a more sustainable environment.
Due to the emissions of energy usage, industries such as construction have a significant impact on the environment. most often construction industries' usage of energy is high, the machines used mostly lean on the fuel and including electricity which results in unnecessary burning of fuels which results in CO_2 emission. Shipping and fabrication of material can also result in a great impact of CO_2 emissions, thus construction can result in hazardous waste where improper disposal affects not only the environment but also people's physical health.

By adopting sustainable construction methods, will help in the reduction of impacts on both environment and health. However, sustainable construction does have more tangible benefits beyond the environmental value, such as the saving in energy spending yearly in addition to the direct saving for each organization such as reducing the amount of waste produced since they in return minimize the fees charged by the waste management company. When a company adopts some efficient vehicles, it results in reducing the fuel costs as well.

World Cup Stadium

World Cup Stadium in Qatar is initiated, the design of world Cup such as Ras Abu Aboud in Doha is going to be fully reusable by the FIFA for the 2022 coming event. The component of the stadium will be recyclable and the building blocks shall have arrived at a port filled with the materials to be used in the stadium. The containers will be used to make the stadiums various parts such as offices and bathrooms. Every step was carefully planned since the early stage of design; it was initiated with the idea of having a reusable stadium for more sustainable aspect. The stadium should as per the planned finish by the next year, and it is one out of seven stadiums among the whole Qatar, out of 1000, more than 90 containers will be used have already arrived.

The proposed stadium will have a cooling technology that is capable of reducing the temperature inside the stadium up to 20°C - 36°F- while the upper tier of the stadium shall be disassembled after the World Cup and then donated to other countries will less development of sports infrastructure. All proposed stadiums have been designed by Albert Speer & Partners a German architect. The applied air conditioners in the stadium will be solar-powered and carbon-neutral provided by Arup from England. After the World Cup of FIFA 2022, the stadium will be disassembled and the containers should be used to build another stadium somewhere else, it’s a good opportunity to reutilize the facility of the stadium.

Construction waste in Qatar

Qatar as a country moving towards new aspects including sustainable development while having a plan to recycle more than 15% of solid waste for a couple of coming years. As the countdown of the FIFA World Cup, many upcoming activities are being under process in order to be delivered on time the for world cup, some process include with the infrastructure development either demolishing or rebuilding , the generated waste should be expected to slightly decrease as stated by Qatar Second National Development Strategy (NDS2). Qatar is also paying a lot of attention the waste recycling, in addition there is noticeable increase in the waste recycling rate and the awareness about domestic waste and its quality which affects the environment where they made it possible to achieve their target of 15% solid waste reduction.

Construction waste in Qatar is second to also affecting the sustainability of the country, the whole generation of waste including construction waste, has increased from 8 million tons in 2008 to be 12 million tons in 2013 , nevertheless it was reduced to 9.8 millions tons in 2014 and reduced to 7.7 millions tons in 2015, so we can see the effort done the reduce the total waste to be around 7 million during 7 years. The hidden reason for this reduction in waste is due to the declining of construction production waste which contributes to around 70-80 percent of the whole waste decomposition. Along with the statistics of 2012, it was clearly shown that around 3-6 percent of the total waste was actually recycled based on the data from Ministry of Development and Statistics. Furthermore, based on Second Voluntary National Review in 2018, it stated that the whole waste has rescued to be around 8.2 million tons in 2017 from 12.1 million tons in 2011 which is significant decrease. The government in Qatar pays a lot of attention to recycled waste, treatment of waste and management of waste, by reducing waste it will also helps improving peoples' health and maintaining a better view of Doha from a sustainable aspect and helps to promote the importance of waste reduction processes. There are certain standards for the recycling of materials including paper, plastic, tires, textile, and glass. In addition to high volume of construction waste such as cement, bricks and tile waste. Their main focus will be on using recycled materials instead of gravel extract in some applications. Qatar Second National Development Strategy (2018) has a lot of goals that helps in achieving sustainable consumption and energy and water and efficiently usage of natural resources. By 2020, Qatar should be able to reduce the consumption of waster by 15 percent, so the total loses due to water per capita for more sustainable approach by National Program for Conservation and Energy Efficiency.

Circular Economy and its importance for the construction sector

The circular economy concept is described as a concept as when the products and materials have highly valued content, unlike old linear economic models as its based on the taking, consuming and finally get rid of that product, the circular economy focuses on complementary loops that takes into considerations the biological cycles where the product decompose by living organisms and the other consideration is the technical aspect where products would not decompose by living organisms. Therefore, the circular economy goal to reduce the loss of resources available as much as possible. So, circular economy reduces the amount of waste until minimum possible amount, when any product is reaching to end of life phase, the materials are usually kept in the economy if possible, where these materials could be productively used for more purposes in the future in order to create more value. Therefore, what is used as a waste of certain products could be turned into valuable resources for many other purposes such as repairing, recycling, refurbishing of material.

there are many opportunities while adopting and moving towards the circular economy concept such as ;

1- enhancing the security of raw material suppliers where there is a mitigation of risks about supply of raw material such as availability and price volatility.
2- innovation where circular economy triggers a larger innovation as a driver for both sectors due to the redesign of products and materials for the purpose of reusing.
3- jobs and growth since the circular economy can create new jobs and enhance growth.
4- Competitiveness where circular economy could bring saving to both consumers and different businesses by reducing efficiency.

So the circular economy would significantly help in reducing the greenhouses gases emission by adopting new methods and technique of waste management in addition to reducing the different kind of waste amount of resources used such as land, material, energy, and water in manufacturing which in return brings positives impacts on the environment.

Figure 1: Circular Economy list of steps as mentioned by eit RawMaterials

Recycling in the Construction Sector and benefits

So recently recycling material has become the focus of many organizations, and since the environment is getting quite popular matter of discussion, the construction recycled material is now much more important than ever. Previously, the disposal of waste was to be sent to landfill, however, now the construction companies are being educated to a new aspect of recycled material in addition to its huge benefits in saving energy and decreasing decomposition of waste. Recycling helps and benefits many organizations in many aspects. So, it helps in the environment aspect by decreasing waste in landfills, saving energy, as for the economic aspect it significantly reduces the cost and helps with the politics.

Decreases waste in landfills

Nowadays, landfills are being overfilled with the waste such that there should be an alternative of disposing, recycling waste. Landfill will be no longer a place to disposal, for the purpose of future, something new should be introduced.

Saving energy

By recycling the waste of construction material, this leads to huge decrease in the consumption of the natural resources around us, according to one of the business owner of construction, if we are recycling materials of construction such as asphalt pavement and so, the importance of recycling waste should not be skipped or neglected at a time where it receives this much attention.

Reduction of cost

By reduction of material used in the construction of recycling them or reusing them, it reduces the transportation cost as well, in addition to reducing the total cost needed to dispose the materials.

Materials to be recycled

Concrete: one of the most used materials to be recycled in construction material and could be used in different markets.

Metals: such as steel, aluminum or copper which can be sent to scrapping yard to be reused.

Asphalt pavement: by recycling asphalt leftovers, massive energy will be saved and it is usually recycled and crushed back into asphalt.

Glass: some types of glass from tile and windows are also recycled however, it depends on the geographic location of the project.

Gypsum: gypsum that is used in drywall can also be recycled into different markets such as cement manufactures and agriculture.

CHAPTER 2 : LITERATURE REVIEW

The main objective of this research is to raise awareness regarding recycling and reuse of waste products, particularly in construction companies. Furthermore, the impact of products on the environment is also observed. In this research, life cycle of products is also analyzed. The study includes the concern for the production of such materials that are hazards for the ecosystem, so to stay away from making such materials LCIA has taken huge data from all over the world. The reason for the Life Cycle Impact Assessment (LCIA) is to give extra data to help evaluate the outcomes from the Stock Analysis to more readily comprehend their natural Importance. Life Cycle Assessment targets such techniques that can help to draw evolution on the construction site. This study is conducted in a great manner and the attention is on lessening energy utilization and the utilization of eco-friendly materials. In the manufacturing business, more consideration is being paid to feasible development techniques. The concept of Circular Economy framework is also discussed as it strengthens the sustainability of environment. It is important to note that circular economy can be applied for construction industries; in fact, we can say that it is a necessary step. The waste at construction site can be reused for another construction project and this would reduce the landfill. In short, this research provides scoping and setting of boundaries for Life Cycle Assessment, impacts of products on environment, importance of recycling objects and significance of circular economy with respect to construction industries.

Behera (2014) explained in his research that the existence of the development industry is to utilize the varieties materials which can substitute the utilization of untouched materials, so as to diminish ecological effect as far as vitality utilization, contamination, and a dangerous atmospheric deviation. The flexibility of concrete as a development material for huge development work lies in its high quality, low upgrade cost and practical over other development materials and Its reliable way of production. A thorough check with respect to the creation and the utilization of RA in concrete is done and an outline on its impact on various properties of RAC is generated. It will help for future research progress in this field. The broad increment in the pace of industrialization, urbanization because of the parallel development in economy and population has utilized concrete as the most non-manageable material as it is devouring the greatest measure of common assets. Waste which was regularly dumped in landfills and caused pollution of soil, water and air from harmful substances the generation and use of reused material in solid, roadway development, and other structural building work and some discourse on the reserve quantity on CO2 outflows have been included. Numerous materials can disturb the nature, and they represent a great danger along with other issues. Dangerous substances are commonly present in structure material since they are utilized, together with cement, for finishing the structure. (Tam, 2018). In addition, the generation of fine synthetic compounds or the treatment of complex waste and contaminated water streams are under discussion in the manufacturing companies. The reason for the Life Cycle Impact Assessment (LCIA) is to give extra data to help to evaluate the outcomes from the material quality analysis to more readily comprehend their natural Importance. The study includes the concern for the production of such materials that are hazards for the ecosystem, so to stay away from making such materials LCIA has taken huge data from all over the world. Life Cycle Assessment targets such techniques that can help to draw evolution on the construction site (Behera, 2014).

The reason for the Life Cycle Impact Assessment (LCIA) is to give extra data to help evaluate the outcomes from the Stock Analysis to more readily comprehend their natural Importance. To resolve issues relating to a complete destructive environment and ecological issues can be minimized by focusing on the on the issue at a time than to solve the next. Life Cycle Assessment targets make a far-reaching evaluation of the earth.

The study by Matthias Buyle (2013) and Finnveden (2009) discussed the life cycle assessment in construction sector, Buyle (2013) focused on eco-friendly materials to be used on construction while Finnveden (2009) studied the life cycle of products used in construction. Buyle focused on the attention that is on lessening energy utilization and the utilization of eco-friendly materials. In the manufacturing business, more consideration is being paid to feasible development techniques. This general expanding approach prompted a universal concern on diminishing the outflow of greenhouse gasses and worldwide warming. In view of significant worth decisions. A characterization of existing testing methods should be done as indicated by the number of types of materials, going from materials to building segments includes the investigation of whole structures. Discussing the investigation of materials and parts is past the extent of this audit; anyway such examinations have demonstrated their worth. The research done by Finnveden (2009) is focused on the construction in the life cycle of products and to show the data related to lifecycle of products and its impacts on the environment. The emphasis is on certain territories where there has been an exceptional methodological advancement. The exploration is finished by separating the procedures into sub-forms or growing the framework limits and incorporate influenced portions of other life cycles in the innovative framework under investigation. Focal point of the creator was on subdivision or framework development that ought to be utilized to maintain a strategic distance from allotment issues. Utilization of building machinery and waste material is helping the researchers to ensure the existence cycle of the items is under controlled check.

Smol (2015) discussed that the point of the circular economy is to lessen or possible use of waste in an ideal way. A significant favorable position of circular economy frameworks is to keep the additional incentive in items for whatever length of time that conceivable and dispose of waste. They keep assets inside the economy when an item has arrived in the production line, with the goal that they can be profitably utilized again and subsequently make further esteem. Ingenuity is a significant factor attributable to which manufacturers focused on the national and international markets. The best thing about utilizing waste is that they do not require any special handling because they are remains of quality products. A great example can be deduced from the prior research in which some female researchers have consulted the panel of textile waste and according to them, by the usage of these waste materials, not only acoustic and thermal conditions of building can be improved but also reduces the impact of energy-related to emission of greenhouse gases and production of different construction materials. The waste of construction materials should be collected properly and recycle so that it can be reused again at new construction site. Furthermore, there was a general consciousness of the economy among the study respondents and momentary participants; there are various significant financial, authoritative and specialized challenges that should be defeated to empower wide-scale adoption at an industry-wide level. The absence of agreements that how the circular economy should go on in that fabricated condition could be a contributing element to this. This apparent absence of industry-wide knowhow and managing issues are responsible for the division of the production network, for example, customers and planners, have little learning on the most proficient method to embrace this. The project managers should create awareness regarding this at least in their circle. Furthermore, the adaptation of this information should be created on a large scale by the government because it is a great problem we are dealing with nowadays (Adams, Thorpe, 2017)

Hui Guo e.t. al (2015) has discussed the importance of reuse of the materials for constructing the different buildings. The cement production is discussed in this article as it can be produced by using different materials and by reusing those materials. The theme of the study is presented in a managed form. The data provided is related to the construction business and raw material production. The environmental effects that have been discussed are of immense importance, also the methods to make such aggregates has used in the cement to lower its cost and harm to the environment. The innovation in cement production with the use of raw material is also of great value (Peng Zhang, 2015). Also in advanced nations, construction waste is arranged to landfill, causing social, ecological, and financial emergencies. In these countries, waste coming from construction exponentially increases because of their fast-financial development, industrialization, and urbanization. His paper intends to look at the probability of reusing solid waste for the creation of new concrete in Ethiopia. Physical and mechanical qualities of (RCA) gained from solid waste are completely inspected (Mohamed. Saleh, 2015).

CHAPTER 3 : LIFE CYCLE ASSESSMENT

Life cycle assessment method

In order to achieve sustainable development, there should be certain methodologies and tools in order to quantify and compare the results of the environmental impact of both provided services or goods. The products are usually made and used in order to fulfill a need, every product has a life, starting with the development or design which is followed by, resources extraction, production (such as manufacturing), consumption of the product and eventually the end of life activities so it passes through many stages such as collecting, reusing, recycling and disposal. All processes or activities results in an impact on the environment due to the emission of resources or products which affect nature in the end, for instance the radiation that comes from environmental exchange.

Life cycle assessment (LCA) methodologies lays in assessing or estimating the environmental impact attributing to the lifecycle of a product including climate change, ozone depletion (stratospheric sphere), acidification and toxicological stress which affects human health and also the ecosystem (REF). The design of any product predetermines the behavior of next phases such as the cars, where the design of it will determine the fuel consumption and the emissions per kilometer used or driven in the usage phase and thus influence the option of recycling after the end of life cycle of products.

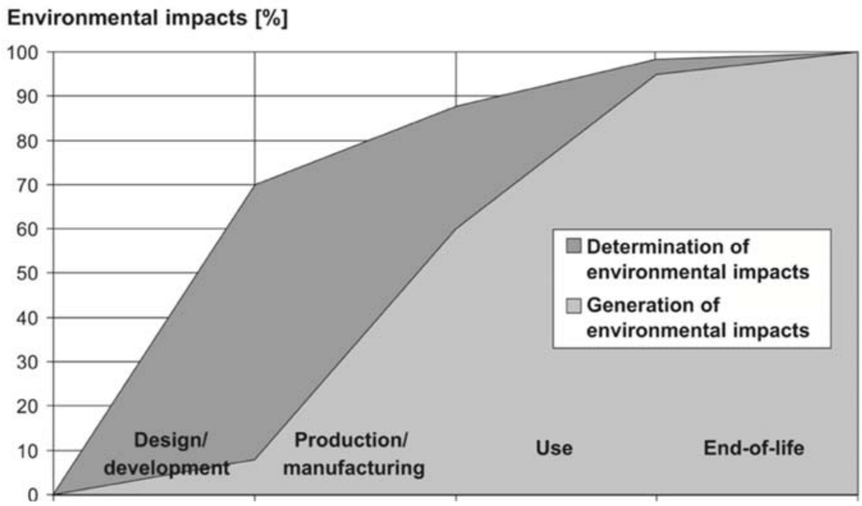

Figure 2: illustrate the environmental impact and the phases of product lifecycle (REF)

goods and services, in addition, to maintain and achieve that aim, the LCA should be carried during the design phase and as early as possible, this is also applied analogously to the improvement and design of any process within the life cycle of that product. The application of LCA helps in maintaining a sustainable design. LCA is a systematic and well planned phased approach that consists of four components which are: definition of goal, impact assessment, inventory analysis, and interpretation (REF).

Goal definition

where it define and describe the process, activity or product, the context will be established such that assessment is to be made in addition to identifying the boundaries and environmental effects for the purpose of assessment and revision.

Impact analysis

Assessing the potential ecological and human effect of water, energy, material usage and environmental release identifies the inventory analysis.

Inventory analysis

Identifying in addition to quantifying energy, material usage, water and environmental release (such as solid waste disposal, air emissions, and wastewater discharge).

Interpretation

Evaluation of the end results of inventory analysis, impact analysis and selects the most appropriate product, service or process while clearly understanding the assumption and uncertainty used in generating the results. Mark Fedkin has developed a system used for process and the boundaries including in the steps of life cycle assessment as shown in figure 3.

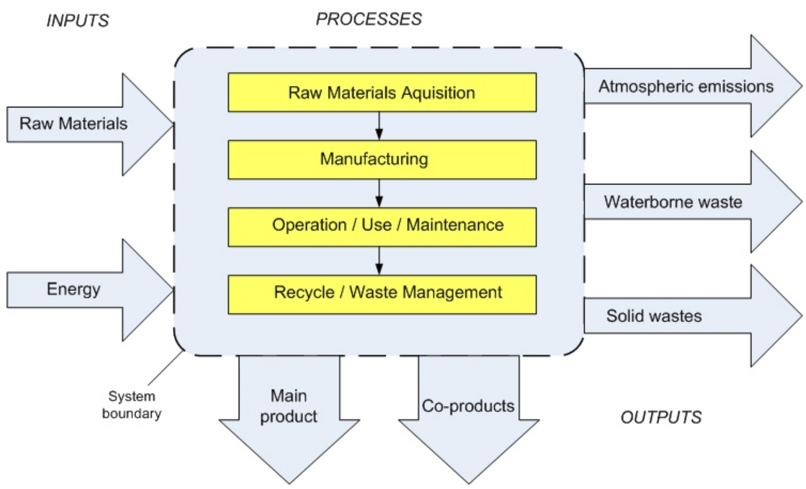

Figure 3 : Methodology of Life Cycle Assessment (REF) by Mark Fedkin.

LCA in decision making

So, be performing LCA, it can be as a tool to help in decision making, LCA can help in developing a systematic evaluation of all the environmental results or consequences in regards to certain products, analyze all the possible trade-off of environmental aspects associated with one or even more specific process or product in order to gain stakeholder acceptance, quantifying all environmental releases to water , air and land during each life cycle of major processes, assessing ecological effect of environmental releases to regions, community and the whole world, comparison of the ecological and health impacts between one or more processes or product. Some situation in decision making could be categorized in both strategic and operational decision, the choosing process between two construction product would be more of an operational decision whereas the choice of doing or implementing sustainability in some process like manufacturing would be more of a strategic decision, LCA could be used in such situations where it helps more in both strategical and operational decisions.

Life Cycle Assessment of Aggregate Recycling in Qatar

All living organisms on earth takes in some raw materials and then excrete wastes. Raw materials which are used by a human, can be reused or recycled as all other organisms. However, an enormous flow including flow of material residues that are produced by humans exceeds the carrying capacity of natural recycling cycle starting from now. The amount of waste generated by humans must be managed or treated in order to reduce their effects on our health in addition to the environment. As economic development and urbanization progress by human-being, the amount of waste generation is exponentially increasing for the past years. According to the World Bank report, the expected world generation would be around 2.59 billion tons per year by the year 2040 and it will reach up to 3.4 billion tons per year by 2050 (REF).

Currently, almost 33 percent of global waste is openly dumped whereas, around 40 percent of the global wastes are landfilled (REF). There is a great effort used on waste management from the upstream at the source by working on the designing out waste, preventing upcoming generation, minimizing and reusing. However, it is only 19 percent of the total wastes that are recycled worldwide (REF).

Based on the Environment Statistics Annual Report 2013 the total existing wastes generated in Qatar is about 1,000,990 tons per year, and 0.4745 tons per capita, which is considered as the 57th highest waste generation per capita in the whole world (REF). However, its recycling rate is around only 3%, which is considered much lower than the world average of 17.4% among the listed countries in the world (REF). Non-recycled wastes are usually landfilled at two waste landfill sites located in Umm Al-Afai and Mesaieed through four current waste transfer stations located in Al-Khor, Dukhan, Doha South, and Doha West. The state of Qatar keens to improve and enhance waste management and treatment in order to minimize negative environmental and health effects caused by different types of wastes. According to the Qatar Environmental Statistics, the total amount of waste has been significantly reduced from 12 million tons in 2012 to be around 8 million tons in 2017 (REF). The majority of the waste, more than 50% of the total is considered construction wastes. By considering that materials consumed in Qatar, mostly are directly imported from overseas or might be processed in Qatar after importing the raw or semi-processed materials coming from overseas, the environmental impacts related to the construction material disposals shall be significant from the life cycle aspect.

The Ministry of Municipality and Environment is promoting waste recycling and the reuse of wastes in the building and construction sector in Qatar (REF). However, there are some preferences locally to the use of new and virgin materials, and recycling the infrastructure for the purpose of material reuse is not yet fully established. Recycling is a critical matter to keep them focusing on the reuse of materials and stop them from contamination due to other waste that has a good economic value. Waste materials can be seen as a valuable resource, if reused properly where recycling materials will be desirable preference in waste management options to reduce the imported virgin material consumption as well as to minimize the waste generation in Qatar.

Based on the survey conducted by the Social and Economic Survey Research Institute (SESRI) at Qatar University about 83% of both expatriates and Qataris views global warming as a serious issue to Qatar, which needs to be resolved. In Qatar, the total carbon emissions coming from fossil fuels are uprising, Qatar is ranked as the world's highest CO_2 emitting country per capita as per World Bank statistics (REF). Mostly, it is caused by the types of emissions generated from gas and oil industrial processes in addition to electricity and water generation. Moreover, more than 60% of CO_2 emissions are originally coming from electricity and heat production, and this is continuously increasing based on the continual production of oil and gas. Carbon dioxide emissions coming from transportation are also increasing significantly, and now it is responsible for around 18% of the total CO_2 emissions in Qatar due to the increasing number of population.

Life cycle sustainability assessment based on economic, social and environmental impacts

Life cycle Sustainability assessment depends upon three types of assessments which are (REF);

LCSA = SLCA + LCA + LCC

LCSA = Life Cycle Sustainability Assessment

LCA = Environmental Life Cycle Assessment

LCC = LCA type Life Cycle Costing

SLCA = Social Life Cycle Assessment

The following sections explain the LCSA with regard to the environmental dimension, the economic dimension and the social dimension of LCSA.

Environmental Impacts

The concept of environmental assessment in life cycle sustainability assessments is concerned about the assessment of resources, materials, energy, and flow of waste in any product life cycle. One of the methods used for the purpose of assessment is using the ISO 14040 standards as a basis for environmental assessment, it is used as a framework to carry out the LCA. After the release of ISO 14040 standards, many studies about LCA have been recently published, and while the methodology of LCA has matured enough over the past years, there are still many fields which needs to receive attention such as the field of assessment of impacts on ecosystem, databases of LCA and quality assurances of LCA (REF). Furthermore, with the rise of awareness in many governments about the concept of integrating the LCA into their top management system while using it for assessing the environments, it can help as a technique for a strategic decision making to maintain and reduce the environmental impacts of any organization and along the rise of awareness in many developed countries, the life cycle assessment is based upon the lesson learned of LCA. Furthermore, the findings of LCA are being distributed or communicated to customers directly like the ecofriendly labels on the different products in order to identify the environmental friendly products. So, in order to use LCA as a technique there are certain phases to follow (REF)

- Goal and scope.
- Inventory of resources use and emissions.
- Impact assessment.
- Interpretation.

State scope and the goal

At first, the scope and goal should be clearly identified, this helps in the assessment and explains ‘who’ and ‘how’ the results will be stated. This step will also include some details such as the boundaries of the system, functional unit, any assumption of the study limitation and impacts. Therefore, his method will be used for allocating the environmental results when there are one or more products function.

Inventory of emissions and resources

The this phase, after the release of emissions of any product to the environment, along with the extraction of the resources from the environment to be grouped into inventory, the flow of the inventory is as shown in the figure 4;

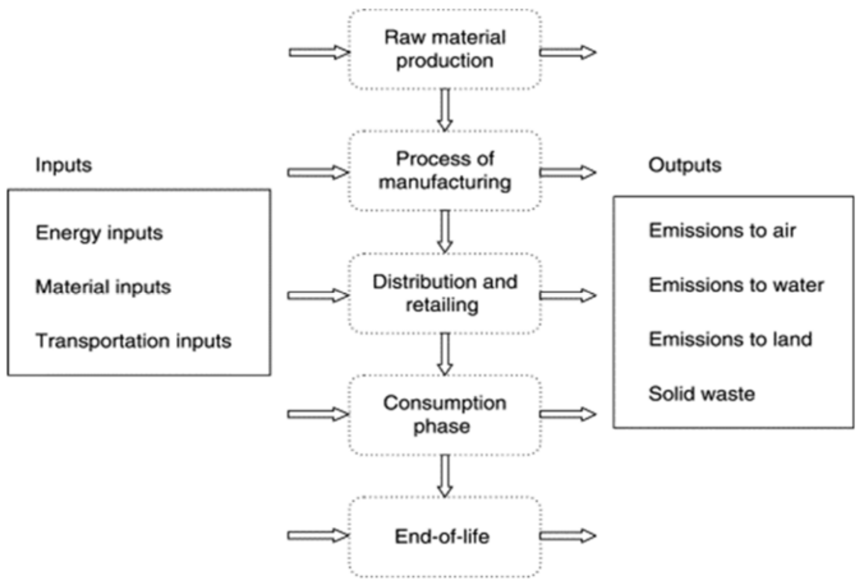

Figure 4: Flows of information needed for a life cycle inventory.

Life cycle impact assessment (environmental impact translation)

In this phase, life cycle impact assessment -LCIA- results would give an indication of environmental interventions with the support of the impact assessment methods. The environmental impacts are assessed at the last level or any intermediate point as shown in figure 5.

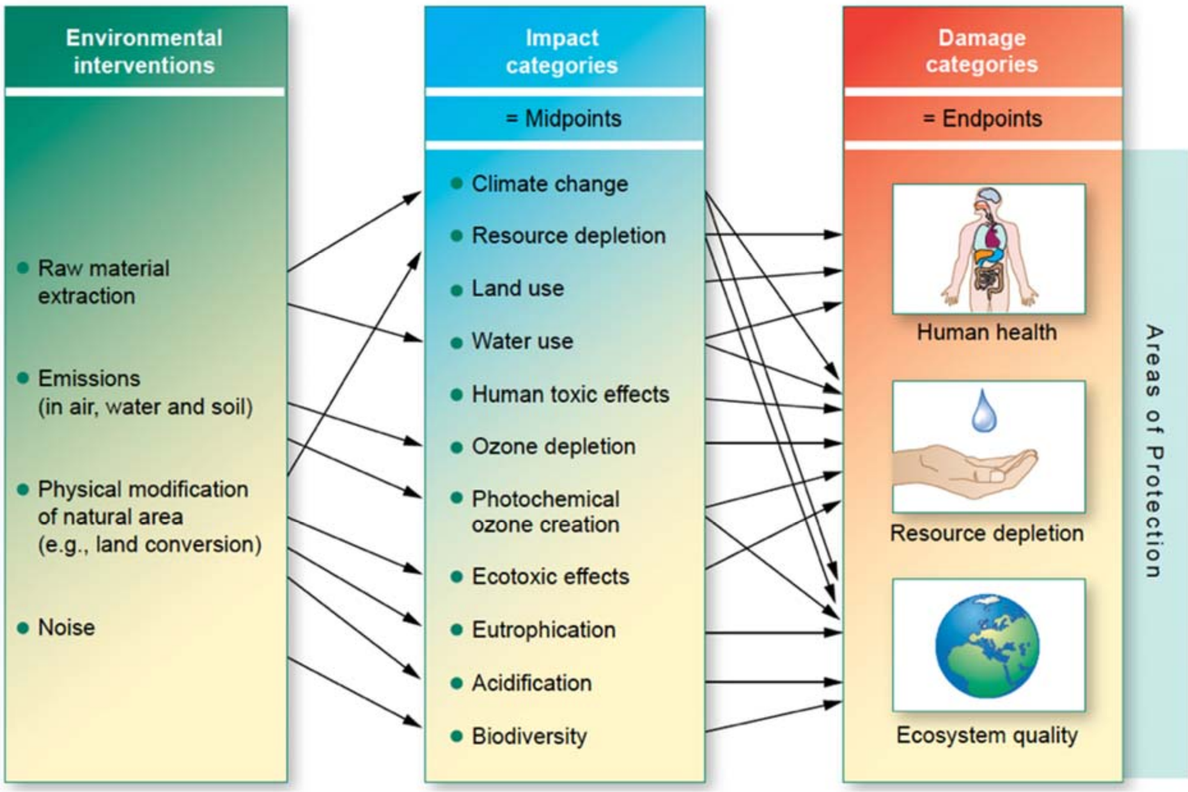

Figure 5: scheme of the environmental LCIA framework

In the classification step, some point are linked to certain midpoint impact categories such as climate change, the information will flow for further meaningful interpretation and processing.

Interpretation

The life cycle interpretation should be done during the final phase, it is necessary for the quantifying, identifying evaluating and checking the results of Life Cycle Impact. The interpretation phase would generate the recommendation and conclusion. Furthermore, it will also evaluate the evaluation of some completeness, consistency, limitation, and sensitivity in order to compile with ISO14040 standards.

Social Impacts

As for the social impacts, it deals with the socio-economic and social criteria of certain products through its life cycle. By identifying the needs of the integration of some social criteria in the LCA, it will be as guidelines for social life cycle assessment. In SLCA, it provides a map for the different stakeholders such that they will be able to assess the socio-economics and social impacts of some products during its life cycle. The social life cycle assessment sees the different potential impacts whether positive or negative on the socio-economics during the product life cycle. These impacts will define how the product could possibly affect the stakeholders. The social life cycle assessment has the ISO 14050 frameworks to follow which acts as guidelines for SLCA. It has four phases consist of scope and goal of the study, impact assessment, inventory, and interpretations.

CHAPTER 4 : METHODOLOGY

Goal and Scope

Concrete is one of the most used material in construction, its mainly used in many forms of construction such as bridges, roads, and buildings. In the old ways of using concrete in construction, the proper mixtures are achieved by mixing the right amount of aggregates and water and then it's simply used on the desired construction such as roads to fill in the base in order to construct. Whereas in the new way of using recycled materials including cyclopean concrete, the process aims for more sustainable construction methods thus, they emphasize the use of recycled materials. The process of using recycled materials in construction base foundation starts with Layering washed graded limestone rock boulders on the site which have certain specifications, and then pressing the excavator bucket against the limestone to achieve compaction and then concreting the first layer with Cyclopean concrete. The project is emphasizing on the construction of the Education City Stadium (ECS) project, the project site was already excavated by another enabling works contractor.

Part of the project's specification for foundation and substructure preparation requirement specifies that areas of the site under raft slab where the foundation stratum is found to be lower than anticipated due to over-excavation shall be backfilled up to the founding stratum.

JPAC JV has developed a methodology for the under raft foundation to use the site excavated boulders (in Cyclopean Concrete), which then helps to conserve resources and minimize the environmental impact of the construction activities.

A Design Modification Report (CDM) was submitted to the client and project PM/CM, which includes the method and the material properties of filling material for areas under the raft foundation using Cyclopean concrete.

The CDM Report also highlights sustainability strategies and environmental management such as;

- Reduced resource use
- Material re-use on site
- Preventing unnecessary transport emission
- Minimizing waste generation
- Dust suppression & control

Inventory analysis

- 45000m^3 of soil and boulders have been excavated.
- Boulders have been cut in specific sizes in order to fulfill the requirements and be used for cyclopean concrete.
- Point Load tests were performed to boulders selected specimens.
- The site has been prepared following the procedures of the approved Method Statement for application of cyclopean concrete fill including full safety control measures.
- Layering of washed graded limestone rock boulders (200mm-400mm in size), mainly two layers of 500mm.

- The limestone rock boulders are excavated material from the site and have strength as per the geotechnical report.
- Full compaction of the limestone areas is not required. Compaction are achieved by pressing the excavator bucket against the limestone.
- With the help of a wheel loader/excavator and a screening bucket the boulders are cleaned and selected by size, and then washed.
- Rejected materials (fines) are then manually selected and removed.
- Limestone at the separation layer is exposed to interlock with above (2nd) formation layer as shown in section below.
- Approximately 18,000m^3 has been concreted for the stadium raft wherein out of, 6500m^3 of boulders from site excavation works were used for the cyclopean concrete.
- After the completion of the whole casting of the cyclopean concrete fill, load-bearing capacity and coring was performed and tested by 3rd party approved laboratory.

Table 1: Table showing the calculation using Cyclopean Concrete

Quantifying Consumptions of Using Cyclopean Concrete	
Raft Slab Volume of Concrete: *13,637 m³*	**Concrete Pouring & Cleaning Fuel Consumption:**
Boulders Used: *6,500 m³*	Concrete pump truck discharge rate: 38 m³/hr.
Hammer Excavator fuel consumption: 32.52 liter/hour	Concrete pump truck fuel consumption: 0.7 l/m³ (26.6 liters per hour)
Breaking of Rocks: ≥ 6 m³/hr. x 6 equipment = 36 m³/hr.	Concrete pouring duration: 13,637 / 38 = ***359 hrs.***
Boulders Fuel Consumption: (6,500 / 36) x 32.52 = ***5,871.7 liters***	Number of Casting (Pouring): 359 hrs. / 8 hrs. operation = ***45***
Moving of Boulders from Excavation Area to Foundation Area:	Pouring of Concrete Fuel Consumption: (45 x 26.6) x 8 hours = ***9,576 liters***
Front wheel loader fuel consumption: 16.43 l/hr.	Concrete pump truck cleaning time: ≥10 minutes
Trips: 6,500 m³ / (4.7 m³ bucket capacity x 0.60 yield loss) = 2,305	Cleaning Fuel Consumption = [(45 x 10) / 60 mins] x 26.6 = ***199.5 liters***
Duration: ≥12 minutes / trip	**Cleaning and Pouring Total Fuel Consumption:** 9,576 + 199.5 = ***9,775.5 liters***
= (2,305 / 60 mins.) x ≥12 minutes = 461 hours	**Transportation Fuel Consumption:**

Quantifying Consumptions of Using Cyclopean Concrete	
Fuel Consumption: 461 hrs. x 16.43 l/hr. = ***7,574.23 liters***	Distance from concrete plant: 40 km
Volume of Concrete used: *13,637 m³*	Mixer Truck Fuel efficiency for empty truck (Km per liter): 1.40
Steel Reinforcement: 13,637 m³ x 115 kg/m³ (Rafts)	Mixer Truck Fuel efficiency for loaded truck (Km per liter): 1.19
= 1,568,255 kg ***(1,568.26 tons)***	Travel & Return Trip Average fuel efficiency per trip (Km per liter): 1.295
Mixer Truck Queuing & Cleaning Fuel Consumption:	Mixer Truck Fuel Consumption per trip: (40X2) / 1.295 = 61.77 liters
Number of Trips (loads): 13,637 m³/ 8 m³ (capacity) = 1,705	Mixer Truck Transportation: 1,705 trips x 61.77 = ***105,318 liters***
Discharging Rate (concrete): ≥2 m³/min	Pump Truck Fuel Efficiency: ≥30 l/100 km
Queuing Time: 8m³ / 2m³ = 4 x 1,705 = ***6,820 minutes***	Pump Truck Transportation: [(30 x 40) / 100] x (45 x 2 way) = ***1,080 liters***
Mixer Truck Cleaning time: ≥5 minutes	**Total Transportation Fuel Consumption:** 105,318 + 1,080 = ***106,398 liters***
= 1,705 x 5 = ***8,525 minutes***	**Total Fuel Consumption:**
Mixer truck fuel consumption: 11.12911 liter/hour	= 5,871.7 + 7,574.23 + 2,846.30 + 9,775.5 + 106,398 = ***132,465.73 liters***
Queuing & Cleaning Total Fuel Consumption: = [(6,820 + 8,525) / 60 mins.] x 11.12911 = ***2,846.30 liters***	**Cleaning of Equipment Water Consumption**: **Concrete Mixer**: ≥200 liters x 1,705 = ***341,000 liters.***

Detailed summary

Raft Slab Casted Volume of Cyclopean Concrete: 18,005 m³

Boulders Used: 6,500 m³ and Concrete Used: 13,637 m³

Add table number here.

Table 2 : Table That Shows The Detailed Process of Cyclopean Concrete

	Method	Machine & Material	Process	Fuel	
1	Excavation/ rock breaking	Hammer excavators	Hammer Excavator fuel consumption: 32.52 liter/hour Breaking of Rocks: ≥ 6 m³/hr. x 6 equipment = 36 m³/hr	Excavation fuel Consumption: (6,500 m³ / 36 m³/hr) x 32.52 liters/ hr = 5,871.7 liters	Excavation of 6,500m2 (10,400 tons) Out of total concrete slab 44437.3076 tons, excavation material is 0.234 kg per kg of total slab.
2	Transport excavated boulders to the destination	Front wheel loader	Front wheel loader fuel cons. 16.43 l/hr. Trips: 6,500 m³ / (4.7 m³ bucket capacity x 0.60 = 2,305. Duration: 12 minutes / trip = (2,305 / 60 mins.) x12 minutes = 461hr	Transport fuel consumption: 461 hrs. x 16.43 l/hr. = 7,574.23 liters	0.234 kg ratio was for 5871.7 liters fuel. 7574.23 liters fuel consumption is equivalent of 0.30185 liter

	Method	Machine & Material	Process	Fuel	
3	Transport of concrete mixer and concrete pump	Concrete mixer and concrete pump	Distance 40 km Mixer Truck Fuel efficiency for empty truck: 1.40 Km per liter Mixer Truck Fuel efficiency for loaded truck: 1.19 Km per liter Travel Return Trip Average fuel efficiency per trip: 1.295 Km per liter Mixer Truck Fuel Consumption per trip: (40X2 km)/ (1.295 km/liter) = 61.77 liters Mixer Truck Transportation:= 105,318 liters	Total Transportation Fuel Consumption: 105,318 + 1,080 = 106,398 liters	Total concrete (13637m3 = 32469 tons) transportation to the site. the trip weight is half. Trip distance is 80km. total ton*km is 1299048ton*km with 1705 trips. Since concrete mix weight is 0.7307kg for 1kg of total concrete slab, for 1kg of concrete slab.
5	Concrete pouring	Concrete pump truck	Concrete pump truck discharge rate: 38 m^3/hr.pump truck fuel consumption: 0.7 l/m^3 (26.6 liters per hour)Concrete pouring duration: 13,637 / 38 = 359 hrs. Number of Casting(Pouring): 45. Pouring Fuel Consumption: 9,576 liters	Pouring Total Fuel Consumption: 9,576 liters	0.234 kg ratio was for 5871.7 liters fuel. 9,576 liters fuel consumption is equivalent of 0.381624 kg

	Method	Machine & Material	Process	Fuel	
6	Cleaning	Concrete mixer	Mixer Truck Cleaning time: ≥5 minutes = 1,705 x 5 = 8,525 minutes Mixer truck fuel consumption: 11.12911 liter/hour	Cleaning Fuel Consumption = 8,525min/60min X 11.12911 liter/hour = 1,581.261 liter. Water Concrete Mixer: ≥200 liters x 1,705 = 341,000 liters	0.234 kg ratio was for 5871.7 liters fuel. 1,581.261 liter fuel consumption is equivalent of 0.063016686 kg
		Concrete pump	Concrete pump truck cleaning time: ≥10 minutes	Cleaning Fuel Consumption = [(45 x 10min) / 60 mins] x 26.6 l/h= 199.5 liters Water Concrete Pump Truck: ≥250 liters x 45 = 11,250 liters	0.234 kg ratio was for 5871.7 liters fuel. 199.5 liter fuel consumption is equivalent of 0.007950508 kg
7	Concrete casting	Material use Volume of Concrete used: 13,637 m³ .,Steel Reinforcement: 13,637 m³ x 115 kg/m³ (Rafts) = 1,568,255 kg			

Flow process of Conventional Concrete

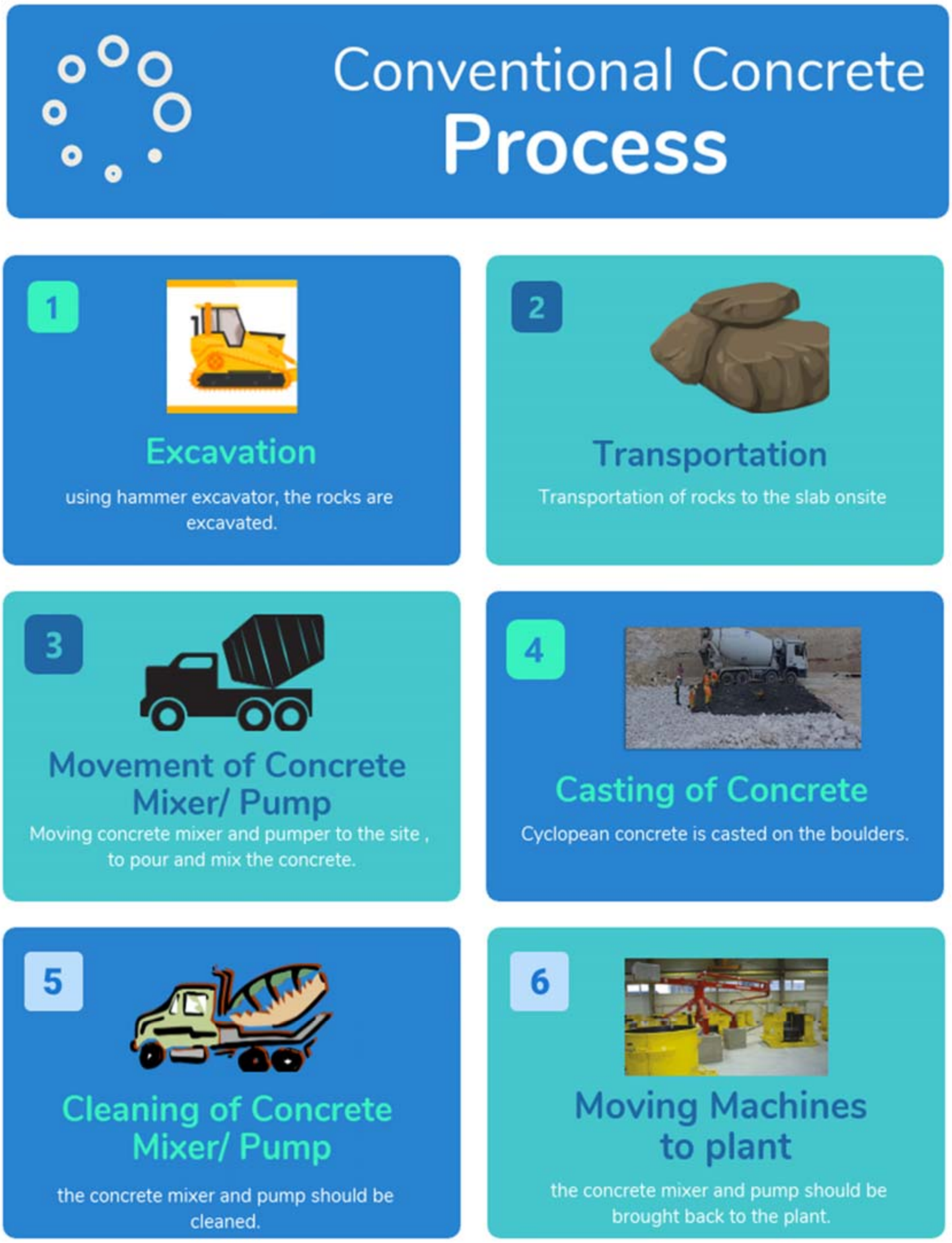

Figure 6: illustrates the flow process using Conventional Concrete

Quantifying Consumptions of Using Conventional Concrete

Table 3 : Table Showing The Calculation Using Conventional Concret

Quantifying Consumptions of Using Conventional Concrete

Breaking of Boulders Fuel Consumption: 5,871.7 liters (refer to cyclopean)	**Concrete Pouring & Cleaning Fuel Consumption:**
Fuel Consumption If Boulders are to be disposed:	Concrete pump truck discharge rate: 38 m³/hr
Tipper Truck Capacity: 22 m³	Concrete pump truck fuel consumption: 0.7 l/m³ (26.6 litres per hour)
Number of Trips: 6,500 m³ / 22 m³ = 296 trips	Concrete pouring duration: 18,005 / 38 = **473.82 hrs**
Distance from dumping site: 50 km	Number of Casting (Pouring): 473.52 hrs. / 8 hrs. operation = **59**
Tipper Truck Fuel efficiency (Km per liter): 2.7201	Pouring of Concrete Fuel Consumption: (59 x 26.6) x 8 hours = ***12,555.2 liters***
Disposal Fuel Consumption: [(50X2) / 2.7201] x 296 = ***10,881.95 liters***	Concrete pump truck cleaning time: ≥10 minutes
Loading of Boulders (for Disposal) Fuel Consumption:	Cleaning Fuel Consumption = [(59 x 10) / 60 mins] x 26.6 = ***261.6 litrers***
Excavator Truck Fuel Consumption: 32.52 liter per hour Bucket capacity: 1.68 m³ (40% for yield loss consideration)	**Cleaning and Pouring Total Fuel Consumption**: 12,555.2 + 261.6 = ***12,816.8 liters***
Number of buckets: 6,500 / (1.68 x 0.40) = 9,673 buckets	**Transportation Fuel Consumption:** Distance from concrete plant: 40 km
Loading duration: (≥1 minute (per bucket) x 9,673) / 60 min = **161.22 hours**	Mixer Truck Fuel efficiency for empty truck (Km per litre): 1.40
Loading Fuel Consumption: 161.22 x 32.52 = ***5,242.90 liters***	Mixer Truck Fuel efficiency for loaded truck (Km per litre): 1.19
Boulders Equivalent Volume of Concrete:	Travel & Return Trip Average fuel efficiency per trip (Km per litre): 1.295
Standard weight of crush rocks per m3 = 1.60 t/m³	Mixer Truck Fuel Consumption per trip: (40X2) / 1.295 = 61.77 litres
= 6,500 m³ (boulders) x 1.60 = 10,400 tons	Mixer Truck Transportation: 2,251 trips x 61.77 = ***139,044 litres***

1 tons (metric) of Concrete Mass = 0.42 m^3	Pump Truck Fuel Efficiency: ≥30 l/100 km
= 10,400 tons x 0.42 = ***4,368 m^3***	Pump Truck Transportation: [(30 x 40) / 100] x (59 x 2 way) = ***1,416 litres***

Total Volume of Concrete: 13,637 m^3 + 4,368 m^3 = ***18,005 m^3***	**Total Transportation Fuel Consumption:** 139,044 + 1,416 = ***140,460 liters***
Mixer Truck Queuing & Cleaning Fuel Consumption:	**Total Fuel Consumption:**
Number of Trips (loads): 18,005 m^3/ 8 m^3 (capacity) = 2,251	= 10,881.95 + 5,242.90 + 3,757.74 + 12,816.8 + 140,460 = ***173,159.40 liters***
Discharging Rate (concrete): ≥2 m^3/min Queuing Time: 8m^3 / 2m^3 = 4 x 2,251 = ***9,004 minutes***	**Cleaning of Equipment Water Consumption**: **Concrete Mixer**: ≥200 liters x 2,251 = ***450,200 liters***
Mixer Truck Cleaning time: ≥5 minutes x 2,251 = ***11,255 minutes*** **.**Mixer truck fuel consumption: 11.12911 liter/hour **Queuing & Cleaning Total Fuel Consumption:** = [(9,004 + 11,255) / (60 mins.)] x 11.12911 = ***3,757.74 liters***	**Concrete Pump Truck:** ≥250 liters x 59 = ***14,750 litres*** **Volume of Concrete Used: 18,005 m^3** **Steel Reinforcement:** 115 kg/m^3 (Rafts) x 18,005 m^3 = ***2,070,575 kg (2,070.6 tons)***

Detailed summary of Conventional concrete

Table 4 : Table Showing The Calculation Using Conventional Concrete

	Method	Machine & Material	Process	Fuel	
1	Excavation/ rock breaking	Hammer excavators	Hammer Excavator fuel consumption: 32.52 liter/hour Breaking of Rocks: ≥ 6 m^3/hr. x 6 equipment = 36 m^3/hr	Excavation fuel Consumption: (6,500 m^3 / 36 m^3/hr) x 32.52 liters/ hr = 5,871.7 liters	Excavation of 6,500m2 (10,400 tons) Out of total concrete slab 44437.3076 tons, excavation material is 0.234 kg per kg of total slab.
2	Transport excavated boulders to the destination	Front wheel loader	Front wheel loader fuel consumption: 16.43 l/hr. Trips: 6,500 m^3 / (4.7 m^3 bucket capacity x 0.60 yield loss) = 2,305. Duration: 461 hours	Transport fuel consumption: 461 hrs. x 16.43 l/hr. = 7,574.23 liters	0.234 kg ratio was for 5871.7 liters fuel. 7574.23 liters fuel consumption is equivalent of 0.30185 liter

	Method	Machine & Material	Process	Fuel	
3	Transport of concrete mixer and concrete pump	Concrete mixer and concrete pump	Distance 40 km Mixer Truck Fuel efficiency for empty truck: 1.40 Km per liter. Mixer Truck Fuel efficiency for loaded truck: 1.19 Km per liter. Travel & Return Trip Average fuel efficiency per trip: 1.295 Km per liter .	Total Transportation Fuel Consumption: 105,318 + 1,080 = 106,398 liters	Total concrete (13637m3 = 32469 tons) transportation to the site. In average, the trip weight is half. Trip distance is 80km. total ton*km is 1299048 ton*km with 1705 trips. Since concrete mix weight is 0.7307kg for 1kg of total concrete slab, for 1kg of concrete slab, concrete travel is 0.029233 ton*km. For 45 trips of concrete pump, 0.000000810 ton*km.
4	Concrete mixer to pump	Concrete mixer	Number of Trips (loads): 13,637 m^3/ 8 m^3 = 1,705. Discharging Rate : 2 m^3/min. Queuing 6,820 minutes fuel consumption: 11.12911 liter/hour	Queuing Total Fuel Consumption: 1,265 liters	0.234 kg ratio was for 5871.7 liters fuel. 1,265 liters fuel consumption is equivalent of 0.050413 liter

	Method	Machine & Material	Process	Fuel	
5	Concrete pouring	Concrete pump truck	discharge rate: 38 m³/hr Concrete pump truck fuel consumption: 0.7 l/m³ (26.6 liters per hour). Concrete pouring duration: 13,637 / 38 = 359 hrs. Number of Casting (Pouring): 359 hrs. / 8 hrs. operation = 45 .Pouring of Concrete Fuel Consumption: (45 x 26.6) x 8 hours = 9,576 liters	Pouring Total Fuel Consumption: 9,576 liters	0.234 kg ratio was for 5871.7 liters fuel. 9,576 liters fuel consumption is equivalent of 0.381624 kg
6	Cleaning	Concrete mixer	Mixer Truck Cleaning time: ≥5 minutes 1,705 x 5 = 8,525 minutes	Cleaning 8,525min/60min X 11.12911 liter/hour = 1,581.261 liter	0.234 kg ratio was for 5871.7 liters fuel. 1,581.261 liter fuel consumption is equivalent of 0.063016686 kg

	Method	Machine & Material	Process	Fuel	
		Concrete pump	Concrete pump truck cleaning time: ≥10 minutes	Water = 341,000 liters Cleaning Fuel Consumption = [(45 x 10min) / 60 mins] x 26.6 l/h= 199.5 liters. Water Concrete Pump Truck: ≥250 liters x 45 = 11,250 liters	0.234 kg ratio was for 5871.7 liters fuel. 199.5 liter fuel consumption is equivalent of 0.007950508 kg
7	Concrete casting	Volume. of Concrete used: 13,637 m³. Steel : (Rafts) = 1,568,255 kg			

Flow process of Cyclopean Concrete

Figure 7: illustrates the flow process using Cyclopean Concrete

- The process of cyclopean concrete are as follows, at first the desired site project is excavated for the base foundation of the stadium, we end up with some boulders where not all of them are sent to the dumping site, we use those between 200mm-400mm in size mainly two layers of 500mm will be layered.
- The area will be Fully compacted , compaction are achieved by pressing the excavator bucket against the limestone.
- wheel loader or excavator and a screening bucket the boulders are cleaned and selected by size, and then washed.
- Other boulders not as per specification will be rejected.
- Limestone at the separation layer is exposed to interlock with above (2nd) formation layer as shown in section below.
- About 18,000m³ has been concreted for the stadium raft and 6500m³ of boulders from site excavation works were used for the cyclopean concrete.

Therefore, the summary is as follows;

Table 5 : Table of Savings Sue to Using Cyclopean Concrete Instead of Conventional concrete

Description	Unit	Conventional Concrete	Cyclopean Concrete	Savings
Cement	tons	5,762	4,365	**1,397**
Sharp Sand	tons	10,803	8,183	**2,620**
Aggregate	tons	21,606	16,366	**5,240**
Reinforcement Steel	tons	2,070.6	1,568.26	**502**

Description	**Unit**	**Conventional Concrete**	**Cyclopean Concrete**	**Savings**
Water in Concrete	m^3	3,168.75	2,400.21	**769**
Water for Cleaning	m^3	464.95	352.25	**113**
Diesel	liters	173,159.40	132,465.73	**40,694**

For the calculation of the prices, it is as follows based on the prices in 2015 in dollars:

Table 6 : Table of Prices of Both Conventional And Cyclopean Concrete.

Description	$ / Unit	Conventional Concrete	Cyclopean Concrete
Cement	$\$/\mathbf{ton}$	$\mathbf{5,762\ x60.42} = \mathbf{348,140.04}$	$\mathbf{4,365\ x\ 60.42} = \mathbf{263,733.3}$
Sharp Sand	$\$/\mathbf{ton}$	$\mathbf{10,803X9.61} = \mathbf{103,816.83}$	$\mathbf{8,183X\ 9.61} = \mathbf{78,638.63}$
Aggregate	$\$/\mathbf{ton}$	$\mathbf{21,606X\ 20.6} = \mathbf{445,083.6}$	$\mathbf{16,366X\ 20.6} = \mathbf{337,139.6}$
Reinforcement Steel	$\$/\mathbf{ton}$	$\mathbf{2,070.6X\ 587.75} = \mathbf{1,216,995.15}$	$\mathbf{1,568.26X\ 587.75} = \mathbf{921,744.815}$
Water in Concrete	$\$/\boldsymbol{m^3}$	$\mathbf{3,168.75\ \ X\ 4.9934} = \mathbf{15,822.84}$	$\mathbf{2,400.21\ \ X\ 4.9934} = \mathbf{11,985.21}$
Water for Cleaning	$\$/\boldsymbol{m^3}$	$\mathbf{464.95\ \ X\ 4.9934} = \mathbf{2,321.68}$	$\mathbf{352.25\ \ X\ 4.9934} = \mathbf{1,758.93}$
Diesel	$\frac{\$}{\mathbf{liter}}$	$\mathbf{173,159.40\ X\ 0.55} = \mathbf{95237.67}$	$\mathbf{132,465.73\ X\ 0.55} = \mathbf{72,856.1515}$

CHAPTER 5 : RESULTS AND DISCUSSION : IMPACT ANALYSIS

Environmental Indicators

According to figure 8 which shows the different environmental indicators taken into considerations, we focused on 4 main indicators which are Carbon dioxide, Methane, Pm10, and Total Water footprint. By having a look at the total water footprint we can notice the difference between the impact of components used inside both conventional and cyclopean concrete, so the direct impact of all components of cyclopean concrete has lower overall results than the conventional concrete. So in order to produce one unit dollar of total water footprint of conventional concrete, the direct amount of cement, sand, reinforcement steel, diesel and aggregates used in conventional concrete are 0.0138ton/$, 0.0034 ton/$, 0.035ton/$, 0.00055$m^3/\$$ and , 0.0038 liters/$ and 0.0247 tons/$ respectively, whereas in cyclopean concrete the amount of cement, sand , reinforcement steel, diesel and aggregates used are 0.0105 ton/$, 0.00258 ton/$, 0.027 ton/$, 0.00042$m^3/\$$, 0.0029 liter/$ and 0.0187 tons/$. Furthermore, as for the gas emissions such as Methane, the direct amount of cement, sand, reinforcement steel, diesel and aggregates used in conventional concrete are 0.000118 ton/$, 0.000038 ton/$, 0.000086 ton/$, 0.00075$m^3/\$$, 0.0000069 liter/$ and 0.00109 tons/$, and in cyclopean 0.000089ton/$, , 0.000029 ton/$, , 0.000065 ton/$, , 0.00057$m^3/\$$, 0.0000052 liter/$ and 0.00082 tons/$. For the emission of CO2, the direct amount of cement, sand, reinforcement steel, diesel and aggregates used in conventional concrete are as follows 0.194 ton/$, 0.0038 ton/$, 0.18 ton/$, 0.00014 $m^3/\$$, 0.07 liter/$ and 0.219 tons/$, and in cyclopean concrete 0.147 ton/$, 0.0029 ton/$, 0.138 ton/$, 0.00011 $m^3/\$$, 0.053 liter/$ and 0.166 tons/$. So for the emission of gases such as Co2 and Methane, the more direct impact coming from specific material, the more affect it has to emit larger amount of that gas to the environment, taking the example of cement used in conventional concrete which is 0.194 and in cyclopean is 0.147, thus cement used in conventional concrete will emit more amount of Carbon dioxide to the surroundings which is threating the sustainability of environment since its direct impact larger than the amount of cyclopean concrete. Lastly, by looking at the PM10 which is a particulate matter emitted to the air with a diameter of 10 micrometers to air which causes pollution, the direct amount of cement, sand, reinforcement steel, diesel and aggregates used in conventional concrete in relation to the emission of PM10 are as follows ; 0.000166 ton/$, 0.000040 ton/$, 0.00027 ton/$, 0.0000071 $\boldsymbol{m^3/\$}$, 0.0000095 liter/$ and 0.00024 tons/$ and as for the cyclopean concrete the amount are ; 0.000126 ton/$, 0.000030 ton/$, 0.00020 ton/$, 0.00000536 $\boldsymbol{m^3/\$}$, 0.00000725 liter/$ and 0.000183 tons/$ so we conclude that the total amount of conventional concrete used is much higher than the amount used in cyclopean concrete and thus, the direct impact on PM10 of conventional concrete component emits much more PM10 into the air than the cyclopean concrete.

So the direct impact of Conventional concrete in Total water footprint, CO2, methane and PM10 direct effect is much higher than Cyclopean concrete.

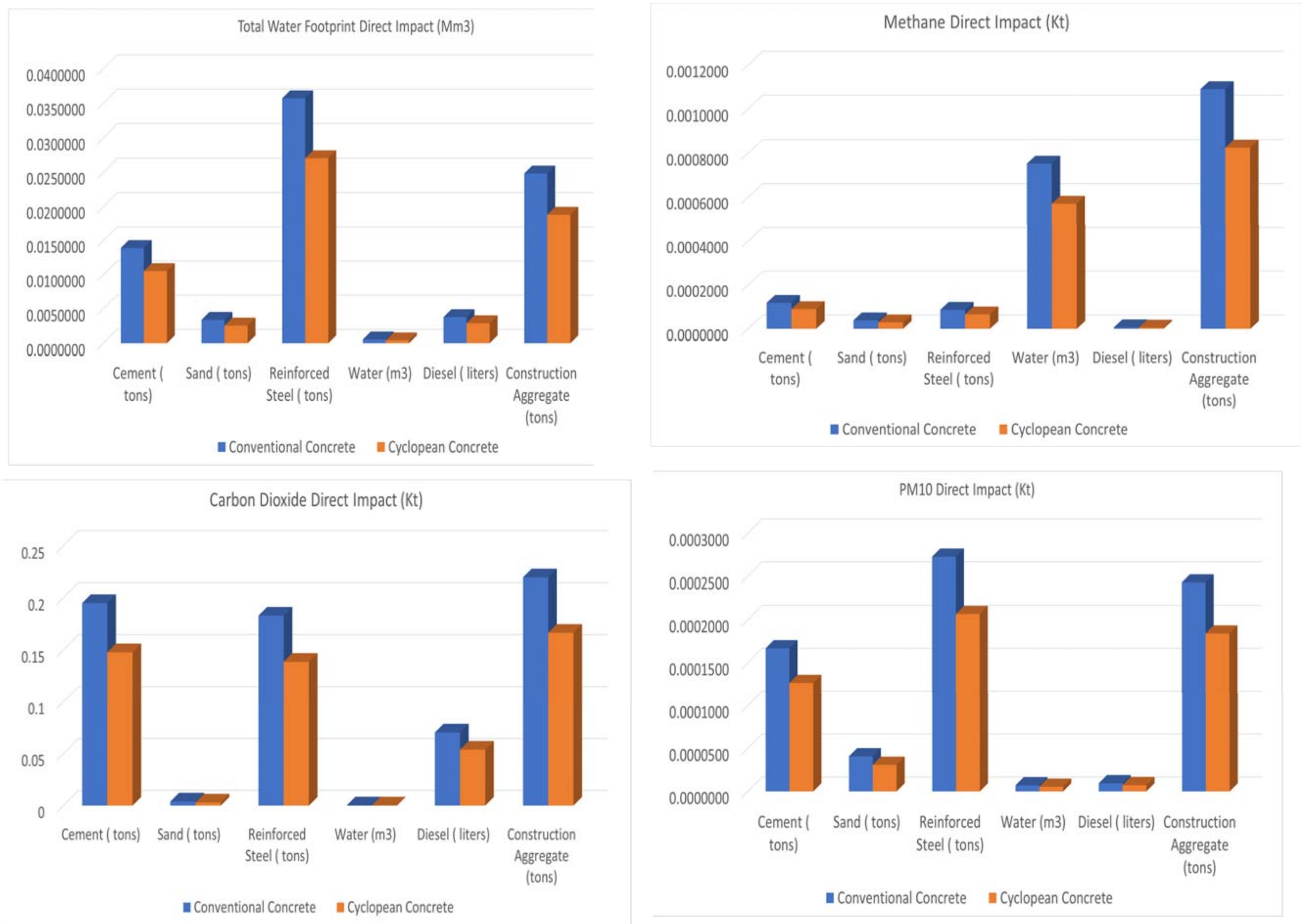

Figure 8 : Figure which shows environmental indicators of Conventional and Cyclopean Concrete.

Social Indicators

By noticing figure 9, which is focusing on the social indicators that are called Herfindahl-Hirschman Index where it is a score given to measure different market concentration and the competition amounts in some industries. So starting with the Nitrous Oxide, according to the figure above, we see that there is a relation between the components of conventional and cyclopean concrete with the N20 which is laughing gas and when it is inhaled it causes loss of sensibility which is classified as a serious problem. So, the amount of cement, sand, reinforcement steel, diesel and aggregates used in conventional concrete are 0.047 ton/$, 0.0154 ton/$, 0.0311 ton/$, 0.0043 $m^3/\$$, 0.0068 liter/$ and 0.086 tons/$, whereas in cyclopean concrete the amount used are as follows ;0.0358 ton/$, 0.0117 ton/$, 0.0235 ton/$, 0.00328 $m^3/\$$, 0.00525-liters/$ and 0.0653 tons/$, so the highest amounts affecting and causing more emissions of N20 are aggregates and cement in both types of concrete but in all cases, conventional concrete values are more so the use of cyclopean concrete is giving more advantages. Coming to the indicator of HFC134a which is a gas when inhaled causes rapid blood concentration and serious problem, so the avoidance of this gas or less exposure to it will be better, be looking at the amount of different components of concrete amount such as cement, sand , reinforcement steel, diesel and aggregates used in conventional concrete in relation to the emission of HFC134a are as follows; 0.2635 ton/$, 0.0862 ton/$,0.1569 ton/$, 0.0147 $m^3/\$$, 0.00286 liter/$ and 0.4474 tons/$, and in cyclopean concrete are ; 0.1996 ton/$, 0.0653 ton/$, 0.1188 ton/$,0.01115 $m^3/\$$,0.00219 liter/$ and 0.3389 tons/$, so the data shows the different values of the HFC134a gas release with the available quantities for each material given and used in both types of concrete

, aggregates followed by cement are causing more emission of HFC134a in both types. Furthermore, by looking at the PM10, where the more exposure to it can cause severe human respiratory affection such as asthma and up until cancer diseases, so the values of conventional concrete used amount in relation to PM10 emissions are

Table 7 : Conventional Concrete Used Amount In Relation To PM10 Emissions

Conventional Concrete	
Cement	$4.33\ X\ 10^{-7}$ tons/$
Sand	$1.05\ X\ 10^{-7}$ tons/$
Reinforcement steel	$7.09\ X\ 10^{-7}$ tons/$
Water	$1.83\ X\ 10^{-8}\ m^3$/$
Diesel	$2.46\ X\ 10^{-8}$ liter/$
Aggregates	$6.311X\ 10^{-7}$ tons/$

Table 8 : Cyclopean Concrete Used Amount in Relation To PM10 Emissions.

Cyclopean Concrete	
Cement	$3.28\ X\ 10^{-7}$ tons/$
Sand	$8.026\ X\ 10^{-8}$ tons/$
Reinforcement steel	$5.37\ X\ 10^{-7}$ tons/$
Water	$1.39\ X\ 10^{-8}\ m^3$/$
Diesel	$1.88X\ 10^{-8}$ liter/$
Aggregates	$4.78\ X\ 10^{-7}$ tons/$

As for the PM2.5 emissions which are as dangerous as being exposed to PM10

The values of Conventional concrete as follows ;

Table 9 : Conventional Concrete Used Amount in Relation to PM2.5 Emissions

Conventional Concrete	
Cement	$8.19\ X\ 10^{-11}$ tons/$
Sand	$1.066\ X\ 10^{-12}$ tons/$
Reinforcement steel	$7.2\ X\ 10^{-12}$ tons/$
Water	$6.46\ X\ 10^{-13}\ m^3$/$
Diesel	$3.7\ X\ 10^{-14}$ liters/$
Aggregates	$4.812X\ 10^{-11}$ tons/$

Table 10 : Cyclopean Concrete Used Amount in Relation to PM2.5 Emissions.

Cyclopean Concrete	
Cement	$6.21\ X\ 10^{-11}$ tons/$
Sand	$8.07\ X\ 10^{-12}$ tons/$
Reinforcement steel	$5.454X\ 10^{-12}$ tons/$
Water	$4.89\ X\ 10^{-13}\ m^3$/$
Diesel	$2.8\ X\ 10^{-14}$ liters/$
Aggregates	$= 3.64X\ 10^{-11}$ tons/$

Environmental indicator percentage Impact of Conventional Concrete

In Figure 10, it represent the impact percentage of environmental indicator of conventional concrete, it shows the different percentage that contributed to different material influence, by looking at the Methane indicator we can see that the largest contribution which affects the emission of Methane is due to 52 % of aggregates, followed by36 % of water , 6% of cement , 4% of reinforced steel ,2% of sand and almost zero contribution of diesel where the value is too small and can be neglected. As for the PM10, we can notice that the largest impact Is due to 37% of reinforced steel, then 33% of aggregates followed by 23% of cement, 5% of sand, and neglected impact of diesel and water with a value that is almost neglected by 1%. As for the total water footprint impact, the maximum impact is due to reinforced steel with an impact percentage of 43 %, then 30% of aggregates, 17% of cement, 5% of diesel, 4% of sand and a neglected value of 1% due to water. Those percentage values represent the effect of those materials on different environmental impacts. for CO_2 emissions, the largest emission is due to 33% aggregates, 29% of cement, 10% of diesel, whereas the effect or the impact of water and sand is almost neglected which means that their effect is almost not considered.

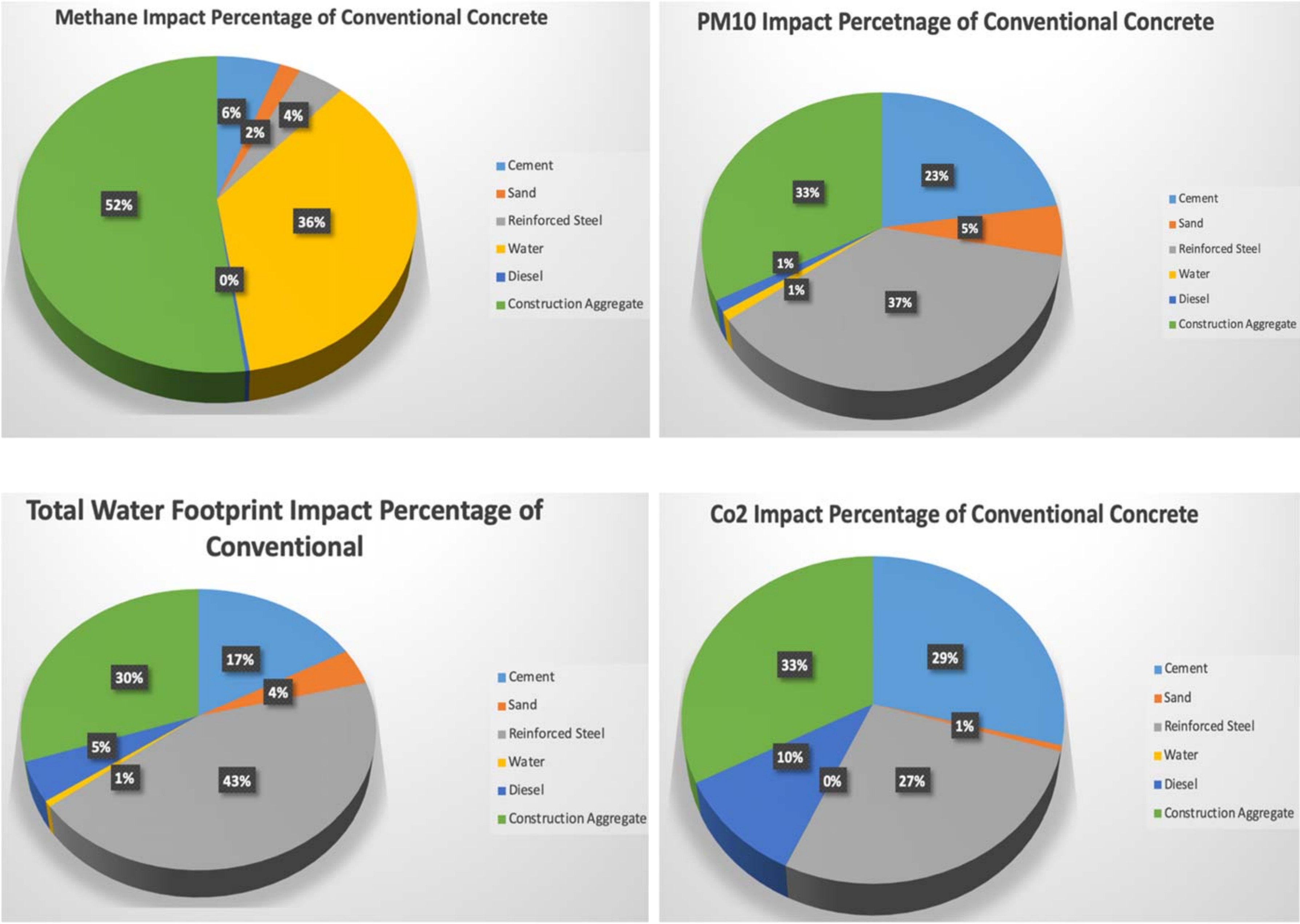

Figure 9: Environmental indicator percentage Impact of Conventional Concrete.

Social indicator percentage Impact of Conventional Concrete

By considering the social indicators, we mentioned that the indicators to be focused on are PM2.5 , N20, HFC134a, and PM10 where all of those indicators are gas and the more emissions of those gases would cause some harness on human's health. by looking at the PM2.5, the most effective that causes the emission of PM2.5 is due to cement of a 55% which is a huge effect, 32 % of aggregates, 7% of sand, 5% of reinforced steel and a 0% of diesel and water. As for the emission of N20 emissions, which is mainly because of 45% of aggregates, 25% of cement, 16% of reinforced steel, 8% of sand, 4% of diesel and 2% of water.

The emissions of those gases can cause severe human disease and thus shouldn't be ignored . for the emission of HFC134a, we notice that the highest impact is due to aggregates by a percent of 46 , then 27% of cement , 16% of reinforced steel , 9% of sand , 2% of water and an almost neglected value of diesel of a value almost 0%. Whereas for the emissions of PM10, there are almost 3 categories which have a high impact on its emissions which are reinforced steel with a percent of 37 %, 33% of aggregates, 23% of cement, those three are the main materials causing the emission of PM10 to be increasing , where the sand has a 5 %, 1% of each diesel and water. In all figures, we can notice that reinforced has a greater impact on all above indicators, so by minimizing the reinforced steel the impact of each of N20, PM10, PM2.5, and HFC134a shall be minimized significantly.

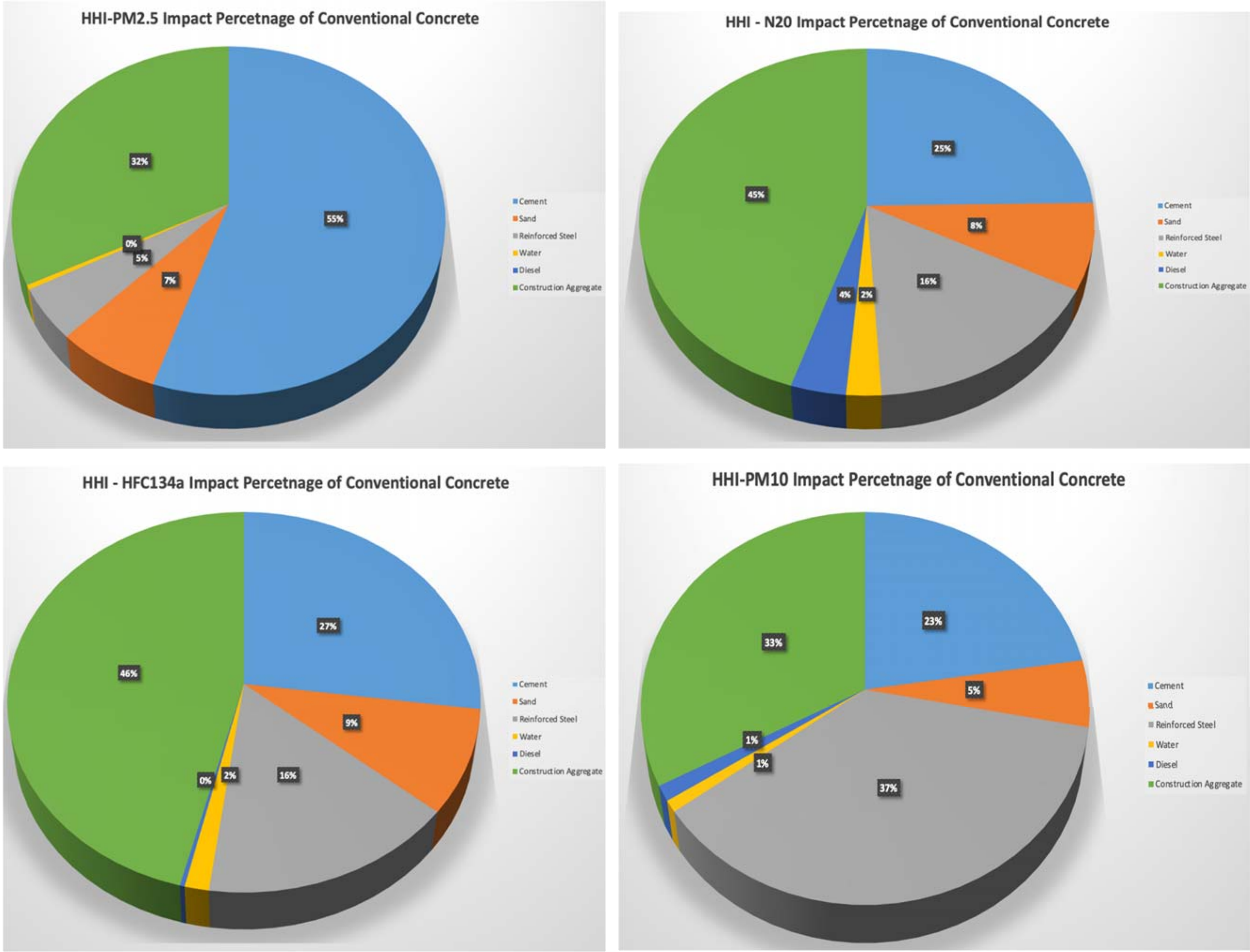

Figure 10: Social indicator percentage Impact of Conventional Concrete.

Environmental indicator percentage Impact of Cyclopean Concrete

In order to have a sustainability environment, environmental indicators shall be taken into consideration. The environmental indicators that are taken into considerations are total water footprint, methane, PM10, and carbon dioxide. So according to the quantities used in cyclopean concrete, the steel reinforcement is having the maximum impact with a percentage of 43%, followed by aggregates 30 %, 17% of cement, 5% of diesel, 4% of sand and 1% of water. By comparing the results of total water footprint of conventional and cyclopean, the results are exactly the same. The impact percentage of cyclopean concrete is exactly the same as conventional concrete, however the difference is in the quantities, where the cyclopean quantities are much less than the conventional concrete. As for the impact of gases such as Methane, Carbon dioxide and PM10, the increase of their emissions will cause higher risks to the environment and thus the sustainability is under threat.

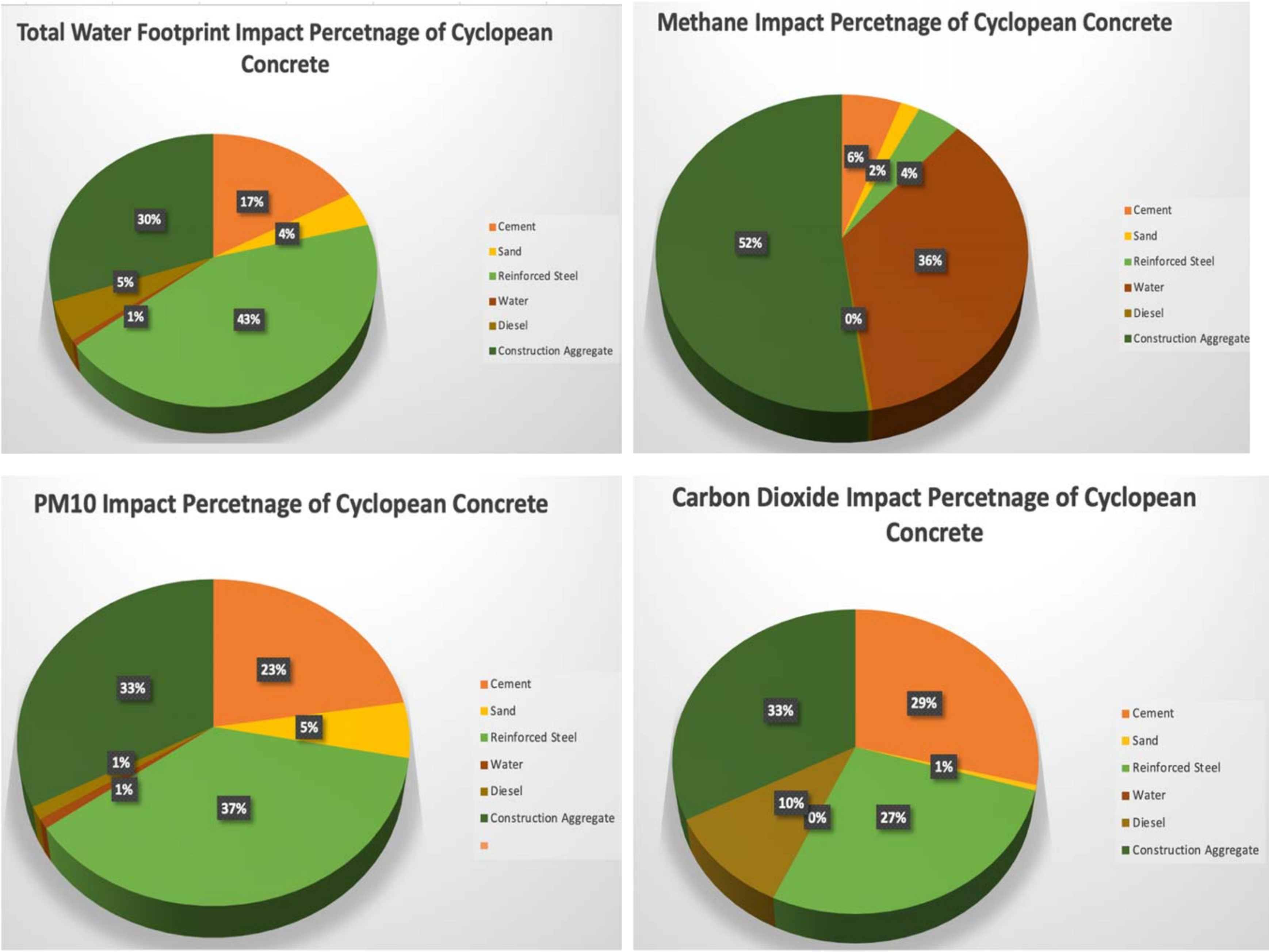

Figure 11: Environmental indicator percentage Impact of Cyclopean Concrete.

Social indicator percentage Impact of Cyclopean Concrete

Social indicators are critical to see the effect of the materials used in either conventional or cyclopean concrete on human's health. By noticing the figure 13, we can relate the effect of the materials used in order to build the cyclopean concrete and its effect on society. Starting with HFC134a which is a gas that causes severe human blood problem in addition to cancer, so the maximum effect is coming from aggregated with a percentage of 46 %, in addition to the effect of cement on causing the emission of HFC134a as well since the direct impact is about 27 %, and the reinforced steel with a 16 %, we could notice that sand, water, and diesel have low impact on the emissions of HFC134a since their impact percentage are 9 %, 2% and 0% respectively. Furthermore, the increase of the release of PM10 is not favorable since it increase the air pollution and thus respiratory side effect can happen, so for the percentage direct impact of cyclopean concrete per materials used are ; 37% of reinforced steel, 33% of aggregates, 23% of cement, 5% of sand and 1% of both diesel and water thus the minimization of both amounts of aggregates, cement, and reinforced steel would reduce the emission of PM10. The nitrous oxide is preferable to below, in order to reduce its effect of losing sensibility of human, the maximum contribution is due to 45% of aggregates, 25% of cement, 16% of reinforced steel, 8 % of sand, 4% of diesel and 2% of water. In addition to, PM2.5 the most impact is coming directly from 55% of cement which is a huge impact, thus Cement shall be minimized as much as possible to reduce its emission, there is 32% of aggregates, 7% of sand, 5% of reinforced steel and 1 %, 0% of water and diesel respectively. The end results show exactly the same percentage of effect on the sustainability and society as conventional concrete, however, the amount used in cyclopean concrete of those materials are less than amount used in conventional concrete thus, the emissions of those gases are less, and their effect on society is less as well.

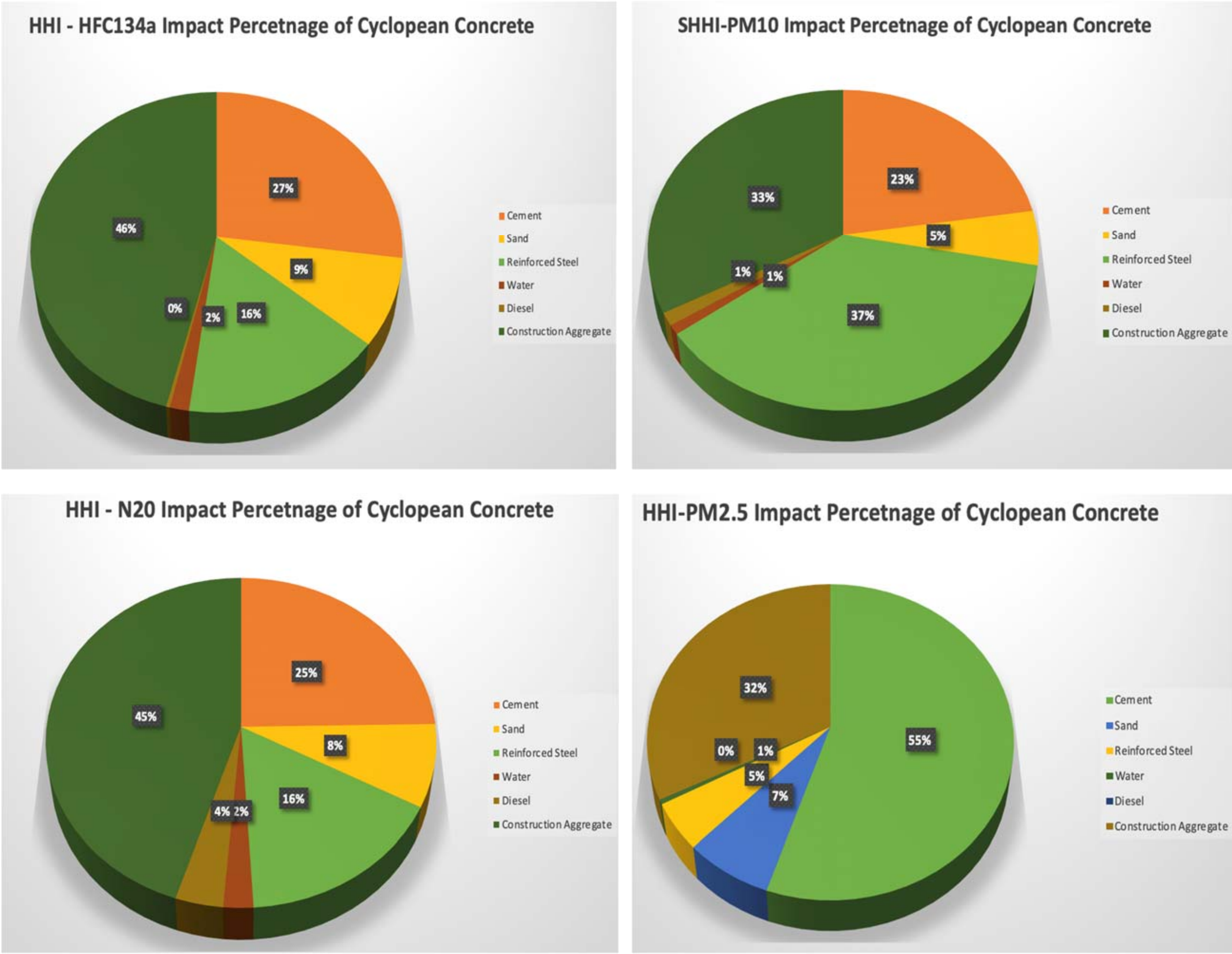

Figure 12: Social indicator percentage Impact of Cyclopean Concrete.

CHAPTER 6 : CONCLUSION AND RECOMMENDATIONS

In conclusion, Life Cycle assessment helps countries to achieve a more sustainable environment, in addition to evaluating the environmental, social and economic impact for the different product's lie cycle. There are different methodology for adopting the life cycle assessment to be followed in order to assess the different life cycles in addition to the different advantages of using Life Cycle Sustainability Assessment such as; it helps organizations organize economic, environmental and social related information in a well-structured form, it shows different trade-offs between the different life cycle impacts and stages by providing a clear picture of positive and negative impacts, it helps in the process of decision making by considering different impacts and it simulates the innovation in value chain sectors. Circular economy is another great concept and by minimizing the amount of waste, when any product is reaching to end of life phase, the materials are kept for further usage in order to create more values. In order to have more sustainable environment and stadiums as well, the use of more sustainable aspect should be implemented, cyclopean concrete is one of the alternatives to conventional concrete, where it helps by layering single layer of selected boulders in size and then the concrete is poured on top of it in the over excavated areas, so the total amount of materials such as cement, water in cement, water for cleaning, reinforcement steel, sand, diesel, and aggregates are kept to minimum and thus the effects on the environment, society, and economy are kept minimum. The different indicators of environment, social and economics have certain impacts related to different materials including those used in the conventional and cyclopean concrete, the higher amount used of those materials, the higher impact it exposes it to surroundings, thus it is more favorable to have it keep them as less as possible. The future should adopt these kinds of sustainability constructions in all sectors for the purpose of having more well performed and sustainable country.

By having a sustainable development, people will be able to meet their needs without affecting the quality of surroundings, but maintaining them. Sustainability aims to have a clean environment, less pollution, reduction of greenhouse gasses and thus human health and less effect on the climate. Circular economy is considered as one of the most important approaches in a systemic way in order to reduce the material usage and improve the amount of usage of materials. In construction field, circular economy plays an important rule for the better use of material available such as cement, sand and aggregated in addition to reduce the amount needed in order to have less waste of components used in construction of building or stadiums, by reducing the amount of each of the components this will lead to less effect on environments, social and economic impacts. By adopting the concept of life cycle assessment, not only construction benefits will results, but a benefit on the while country. Minimizing the waste resulting from construction field could also minimize the total impact coming from diesel, water , aggregates , sand and cement as well in addition to its effect on the emissions of different gases and its effect on both environment and social impacts. Construction in Qatar can take a total new way of buildings by including the cyclopean concrete instead of conventional concrete, since the reduction of material can results in many benefits , and by changing the way that buildings, stadium and houses are built can also affect the economics of Qatar significantly since by reducing the different amounts needed in construction this would lead to the rise of Qatar economically. Qatar is becoming one of the highest excellence achievements in the whole world , along with its good performance and productivity in the field of construction, adopting many new aspects of sustainability could result in less carbon dioxide, PM2.5 M PM10 HCF134a emissions and its effect on the environment and society of Qatar.

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APPENDIX

Appendix A : Tables

A. 1 Table That Shows Different Indicators Of Materials and Minerals

	Total Impacts/Impacts from all the other sectors included	Total demand ($)	Total ($)	Total Intermediate ($)	MINERALS						
					Copper (Cu	Lead (t/$)	Zinc (Zn) (t	Gold (t/$)	Mining anc	Iron (Fe) (t/$)	
Cement	Cement manufacturing	1	1.74817E-06	7.48174E-07	7.89E-06	3.15E-07	3.14E-07	7.23E-06	2.6E-07	1.29E-06	
Sand	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	1	1.69542E-06	6.95423E-07	3.68E-05	1.47E-06	1.47E-06	2.24E-06	4.03E-05	5.4E-06	
Reinforced Steel	Iron and steel mills and ferroalloy manufacturing	1	1.98092E-06	9.80922E-07	2.84E-05	1.13E-06	1.13E-06	1.37E-05	1.2E-07	0.000498	
	Steel product manufacturing from purchased steel	1	1.98856E-06	9.88563E-07	2.18E-05	8.73E-07	8.7E-07	1.34E-05	4.14E-08	9.18E-05	
Water	Water, sewage and other systems	1	1.41701E-06	4.17005E-07	1.49E-06	5.95E-08	5.93E-08	4.11E-07	1.18E-07	5.06E-07	
Diesel	Petroleum refineries	1	1.70632E-06	7.06316E-07	4.25E-06	1.7E-07	1.69E-07	1.93E-06	2.81E-08	9.48E-07	
Construction	Ready-mix concrete manufacturing	1	1.89165E-06	8.91651E-07	1.16E-05	4.64E-07	4.62E-07	3.14E-06	4.18E-06	1.45E-06	
Aggregate	Other concrete product manufacturing	1	1.72321E-06	7.23211E-07	8.05E-06	3.22E-07	3.21E-07	3.46E-06	2.55E-07	1.18E-05	C

	Direct Impacts/Impacts from only the given sector	Total demand ($)	Total ($)	Total Intermediate ($)	MINERALS						
					Copper (Cu	Lead (t/$)	Zinc (Zn) (t	Gold (t/$)	Mining anc	Iron (Fe) (t/$)	
Cement	Cement manufacturing	1	1.02948E-06	4.61042E-07	0	0	0	0	0	0	
Sand	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	1	1.01772E-06	4.17058E-07	0	0	0	0	3.98E-05	0	
Reinforced Steel	Iron and steel mills and ferroalloy manufacturing	1	1.07731E-06	6.10186E-07	0	0	0	0	0	0	
	Steel product manufacturing from purchased steel	1	1.07235E-06	5.91013E-07	0	0	0	0	0	0	
Water	Water, sewage and other systems	1	1.00004E-06	2.67887E-07	0	0	0	0	0	0	
Diesel	Petroleum refineries	1	1.07386E-06	4.46039E-07	0	0	0	0	0	0	
Construction	Ready-mix concrete manufacturing	1	1.01097E-06	5.31616E-07	0	0	0	0	0	0	
Aggregate	Other concrete product manufacturing	1	1.01151E-06	4.24343E-07	0	0	0	0	0	0	C

A. 2 : Table That Shows Different Indicators Of Materials in Energy Comspumption

	Total Impacts/Impacts from all the other sectors included	Total demand ($)	Total ($)	Total Intermediate ($)	ENERGY CONSUMPTION						
					Coal (TJ/$)	Natural Ga	Oil (TJ/$)	Biomass (T	Solar (TJ/$	Wind (TJ/$	Hydro (TJ/$)
Cement	Cement manufacturing	1	1.74817E-06	7.48174E-07	6.14E-06	4.75E-06	5.34E-06	6.3E-07	7.68E-09	1.23E-07	3.27237E-07
Sand	Sand, gravel, clay, and ceramic and refractory minera	1	1.69542E-06	6.95423E-07	2.56E-06	1.26E-06	2.76E-06	2.87E-07	3.76E-09	6.03E-08	1.6045E-07
Reinforced Steel	Iron and steel mills and ferroalloy manufacturing	1	1.98092E-06	9.80922E-07	4.33E-06	3.66E-06	9.82E-06	7.01E-07	4.65E-09	7.44E-08	1.98141E-07
	Steel product manufacturing from purchased steel	1	1.98856E-06	9.88563E-07	2.94E-06	3.32E-06	4.66E-06	3.41E-07	2.34E-09	3.74E-08	9.96277E-08
Water	Water, sewage and other systems	1	1.41701E-06	4.17005E-07	2.07E-05	7.01E-06	-6E-07	1.06E-06	3.1E-08	4.96E-07	1.32105E-06
Diesel	Petroleum refineries	1	1.70632E-06	7.06316E-07	1.51E-06	6.39E-06	4.61E-06	-2.9E-07	1.75E-09	2.81E-08	7.46971E-08
Construction	Ready-mix concrete manufacturing	1	1.89165E-06	8.91651E-07	2.81E-06	4.02E-06	5.95E-06	4.59E-07	2.31E-09	3.7E-08	9.85999E-08
Aggregate	Other concrete product manufacturing	1	1.72321E-06	7.23211E-07	1.98E-06	3.15E-06	3.19E-06	2.88E-07	1.39E-09	2.23E-08	5.92372E-08

	Direct Impacts/Impacts from only the given sector	Total demand ($)	Total ($)	Total Intermediate ($)	ENERGY CONSUMPTION						
					Coal (TJ/$)	Natural Ga	Oil (TJ/$)	Biomass (T	Solar (TJ/$	Wind (TJ/$	Hydro (TJ/$)
Cement	Cement manufacturing	1	1.02948E-06	4.61042E-07	9.16E-07	2.36E-06	1.02E-06	9.11E-08	0	0	0
Sand	Sand, gravel, clay, and ceramic and refractory minera	1	1.01772E-06	4.17058E-07	0	1.36E-08	1.56E-07	8.34E-09	0	0	0
Reinforced Steel	Iron and steel mills and ferroalloy manufacturing	1	1.07731E-06	6.10186E-07	1.13E-06	2.01E-06	4.71E-07	1.35E-08	0	0	0
	Steel product manufacturing from purchased steel	1	1.07235E-06	5.91013E-07	1.13E-06	2.01E-06	4.7E-07	1.35E-08	0	0	0
Water	Water, sewage and other systems	1	1.00004E-06	2.67887E-07	2.03E-05	6.7E-06	-1.6E-06	9.76E-07	3.04E-08	4.86E-07	1.29398E-06
Diesel	Petroleum refineries	1	1.07386E-06	4.46039E-07	3.06E-07	3.58E-06	3.78E-06	-4E-07	0	0	0
Construction	Ready-mix concrete manufacturing	1	1.01097E-06	5.31616E-07	1.08E-06	2.77E-06	1.2E-06	1.07E-07	0	0	0
Aggregate	Other concrete product manufacturing	1	1.01151E-06	4.24343E-07	8.8E-07	2.27E-06	9.83E-07	8.76E-08	0	0	0

A. 3 : Table That Shows Different Indicators Of Materials and The Environmental Indicators

	Total Impacts/Impacts from all the other sectors included	Total demand ($)	Total ($)	Total Intermediate ($)	ENVIRONMENTAL INDICATORS											
					Carbon dioxid	Methane (CH4)	Carbonmonoxi	HFC-134a (Kt/	HFC-143a (Kt/$	HFC-125 (Kt/$)	PM10 (Kt/$)	PM2.5 (kg/$)	Dinitrogen oxid	VOC (Kt/$)	SO2 (Kt/$)	Total water footprint (Mm3/yr.$)
Cement	Cement manufacturing	1	1.74817E-06	7.48174E-07	1.327E-06	3.92251E-09	3.09126E-09	4.9948E-10	5.18058E-10	5.08722E-10	7.09913E-10	9.46251E-14	4.63994E-10	1.89959E-09	2.52238E-09	6.41553E-08
Sand	Sand, gravel, clay, and ceramic and refractory minerals n	1	1.69542E-06	6.95423E-07	4.9368E-07	2.44964E-09	3.95309E-09	5.0212E-10	5.20978E-10	5.11537E-10	5.4544E-10	4.15852E-14	4.64417E-10	1.37593E-09	1.53627E-09	5.56876E-08
Reinforced	Iron and steel mills and ferroalloy manufacturing	1	1.98092E-06	9.80922E-07	7.7044E-07	6.74788E-09	1.42069E-08	2.2972E-10	2.38213E-10	2.33988E-10	4.92347E-10	9.21934E-15	2.45249E-10	2.57187E-09	2.67579E-09	6.35047E-08
Steel	Steel product manufacturing from purchased steel	1	1.98856E-06	9.88563E-07	4.5095E-07	2.37177E-09	5.47864E-09	2.9107E-10	3.01909E-10	2.96561E-10	3.70372E-10	5.27634E-15	2.83838E-10	1.25112E-09	1.31936E-09	6.93572E-08
Water	Water, sewage and other systems	1	1.41701E-06	4.17005E-07	1.0025E-07	4.19178E-08	1.07642E-09	4.3379E-10	4.50082E-10	4.41923E-10	4.31857E-10	1.42591E-14	6.05705E-10	1.44274E-09	5.77224E-10	3.86915E-08
Diesel	Petroleum refineries	1	1.70632E-06	7.06316E-07	9.4213E-07	9.49787E-09	1.13081E-09	5.2078E-11	5.38185E-11	5.288E-11	1.65273E-10	9.6547E-16	2.16724E-10	4.87075E-09	1.25284E-09	5.79462E-08
Construction	Ready-mix concrete manufacturing	1	1.89165E-06	8.91651E-07	1.3539E-06	1.59747E-09	1.04781E-08	3.0235E-10	3.13322E-10	3.07693E-10	5.27113E-10	2.10264E-14	3.13068E-10	1.73155E-09	1.11229E-09	6.57339E-08
Aggregate	Other concrete product manufacturing	1	1.72321E-06	7.23211E-07	8.3294E-07	1.32876E-09	3.28705E-09	4.4697E-10	4.63506E-10	4.55206E-10	5.88642E-10	9.60827E-15	4.08395E-10	1.06808E-09	9.43767E-10	5.41706E-08

	Direct Impacts/Impacts from only the given sector	Total demand ($)	Total ($)	Total Intermediate ($)	ENVIRONMENTAL INDICATORS											
					Carbon dioxid	Methane (CH4)	Carbonmonoxi	HFC-134a (Kt/	HFC-143a (Kt/$	HFC-125 (Kt/$)	PM10 (Kt/$)	PM2.5 (kg/$)	Dinitrogen oxid	VOC (Kt/$)	SO2 (Kt/$)	Total water footprint (Mm3/yr.$)
Cement	Cement manufacturing	1	1.02948E-06	4.61042E-07	5.6008E-07	3.40078E-10	4.70329E-10	3.7818E-10	3.92453E-10	3.85318E-10	4.78882E-10	9.05698E-14	3.2589E-10	3.28164E-10	4.38827E-10	3.98648E-08
Sand	Sand, gravel, clay, and ceramic and refractory minerals n	1	1.01772E-06	4.17058E-07	3.7295E-08	3.72003E-10	5.0254E-10	4.151E-10	4.30766E-10	4.22934E-10	3.92584E-10	3.95023E-14	3.56754E-10	3.57085E-10	4.58457E-10	3.28183E-08
Reinforced	Iron and steel mills and ferroalloy manufacturing	1	1.07731E-06	6.10186E-07	1.5034E-07	7.12519E-11	9.09674E-09	6.443E-11	6.68611E-11	6.56454E-11	2.24102E-10	2.27589E-15	6.13369E-11	1.09094E-10	1.22768E-09	2.93104E-08
Steel	Steel product manufacturing from purchased steel	1	1.07235E-06	5.91013E-07	6.2624E-08	1.68218E-10	2.88775E-10	1.804E-10	1.8721E-10	1.83807E-10	1.79941E-10	2.49495E-15	1.59926E-10	1.71191E-10	3.18429E-10	4.01089E-08
Water	Water, sewage and other systems	1	1.00004E-06	2.67887E-07	8.2057E-09	4.15195E-08	4.79377E-10	4.054E-10	4.20702E-10	4.13053E-10	3.89919E-10	1.36896E-14	5.72734E-10	1.23026E-09	3.63909E-10	3.06858E-08
Diesel	Petroleum refineries	1	1.07386E-06	4.46039E-07	7.3859E-07	7.21699E-11	1.97621E-10	1.5029E-11	1.55959E-11	1.53123E-11	9.9469E-11	1.47647E-16	1.72865E-10	5.10144E-10	7.20616E-10	3.99836E-08
Construction	Ready-mix concrete manufacturing	1	1.01097E-06	5.31616E-07	6.7014E-07	1.3927E-10	2.37189E-10	1.4958E-10	1.55226E-10	1.52404E-10	2.97686E-10	2.62941E-15	1.32447E-10	1.41432E-10	2.60215E-10	2.88723E-08
Aggregate	Other concrete product manufacturing	1	1.01151E-06	4.24343E-07	5.4426E-07	3.16611E-10	4.40184E-10	3.5181E-10	3.65088E-10	3.5845E-10	4.51098E-10	3.92473E-15	3.0335E-10	3.05885E-10	4.12717E-10	2.96334E-08

A. 4 : Table That Shows Different Indicators Of Materials and The Socail Indicators

$)	Total Impacts/Impacts from all the other sectors included	Total demand ($)	Total ($)	Total Intermediate ($)	SOCIAL INDICATORS												
					Employment	Tax ($M/$)	Injuries(fatal)(	Injuries(nonfat	Income (00	HHI - CO2 (DAL	HHI - CH4 (DAL	HHI - PM2.5 (D	HHI - PM10 (D/	HHI - N20 (D	HHI - HFC134a	HHI - HFC1	HHI - HFC125 (DALY/$)
Cement	Cement manufacturing	1	1.74817E-06	7.48174E-07	3.2586E-06	2.95646E-08	1.91134E-09	2.43732E-10	0.000344	1.8578E-06	1.37288E-07	2.46025E-17	1.84577E-13	1.936E-07	9.99968E-07	5.48E-07	2.49274E-06
Sand	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	1	1.69542E-06	6.95423E-07	4.6869E-06	3.04135E-08	3.55358E-10	2.69969E-10	0.000485	6.91145E-07	8.57373E-08	1.08121E-17	1.41814E-13	1.938E-07	1.00524E-06	5.51E-07	2.50653E-06
Reinforced Steel	Iron and steel mills and ferroalloy manufacturing	1	1.98092E-06	9.80922E-07	4.1962E-06	3.50283E-08	2.25891E-10	3.41839E-10	0.000381	1.07862E-06	2.36176E-07	2.39703E-18	1.2801E-13	1.023E-07	4.59908E-07	2.52E-07	1.14654E-06
	Steel product manufacturing from purchased steel	1	1.98856E-06	9.88563E-07	4.7089E-06	2.66385E-08	2.88608E-10	3.45717E-10	0.000417	6.31334E-07	8.3012E-08	1.37185E-18	9.62967E-14	1.184E-07	5.82729E-07	3.2E-07	1.45315E-06
Water	Water, sewage and other systems	1	1.41701E-06	4.17005E-07	5.2025E-06	3.54355E-08	2.70346E-10	2.20417E-10	0.000423	1.40352E-07	1.46712E-06	3.70738E-18	1.12283E-13	2.527E-07	8.68457E-07	4.76E-07	2.16542E-06
Diesel	Petroleum refineries	1	1.70632E-06	7.06316E-07	1.7633E-06	2.77336E-08	8.4697E-11	1.03467E-10	0.000127	1.31898E-06	3.32425E-07	2.51022E-19	4.29711E-14	9.042E-08	1.04261E-07	5.7E-08	2.59112E-07
Construction Aggregate	Ready-mix concrete manufacturing	1	1.89165E-06	8.91651E-07	5.0205E-06	2.68355E-08	8.67919E-10	3.16069E-10	0.000428	1.89546E-06	5.59114E-08	5.46687E-18	1.37049E-13	1.306E-07	6.05299E-07	3.32E-07	1.5077E-06
	Other concrete product manufacturing	1	1.72321E-06	7.23211E-07	5.3009E-06	2.05096E-08	6.74339E-10	4.33806E-10	0.000502	1.16611E-06	4.65064E-08	2.49815E-18	1.53047E-13	1.704E-07	8.94837E-07	4.91E-07	2.23051E-06

$)	Direct Impacts/Impacts from only the given sector	Total demand ($)	Total ($)	Total Intermediate ($)	SOCIAL INDICATORS												
					Employment	Tax ($M/$)	Injuries(fatal)(	Injuries(nonfat	Income (00	HHI - CO2 (DAL	HHI - CH4 (DAL	HHI - PM2.5 (D	HHI - PM10 (D/	HHI - N20 (D	HHI - HFC134a	HHI - HFC1	HHI - HFC125 (DALY/$)
Cement	Cement manufacturing	1	1.02948E-06	4.61042E-07	1.0861E-06	6.57016E-09	1.78388E-09	2.7115E-11	0.000189	7.84111E-07	1.19027E-08	2.35481E-17	1.24509E-13	1.36E-07	7.57121E-07	4.15E-07	1.88806E-06
Sand	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	1	1.01772E-06	4.17058E-07	2.2753E-06	1.20787E-08	2.34963E-10	5.9524E-11	0.000332	5.22125E-08	1.30201E-08	1.02706E-17	1.02072E-13	1.488E-07	8.31034E-07	4.56E-07	2.07238E-06
Reinforced Steel	Iron and steel mills and ferroalloy manufacturing	1	1.07731E-06	6.10186E-07	9.6457E-07	5.61139E-09	2.43131E-11	0	0.000183	2.1047E-07	2.49382E-09	5.91731E-19	5.82666E-14	2.559E-08	1.28988E-07	7.08E-08	3.21663E-07
	Steel product manufacturing from purchased steel	1	1.07235E-06	5.91013E-07	1.7461E-06	2.4833E-09	1.36153E-10	9.66686E-11	0.000221	8.76738E-08	5.88765E-09	6.48688E-19	4.67846E-14	6.672E-08	3.61166E-07	1.98E-07	9.00652E-07
Water	Water, sewage and other systems	1	1.00004E-06	2.67887E-07	3.3879E-06	2.51539E-08	2.29474E-10	1.30035E-10	0.000311	1.1488E-08	1.45318E-06	3.55929E-18	1.01379E-13	2.389E-07	8.11618E-07	4.45E-07	2.02396E-06
Diesel	Petroleum refineries	1	1.07386E-06	4.46039E-07	2.2767E-07	1.79612E-09	1.13425E-11	1.07753E-12	2.62E-05	1.03403E-06	2.52595E-09	3.83882E-20	2.58619E-14	7.212E-08	3.00876E-08	1.65E-08	7.50304E-08
Construction Aggregate	Ready-mix concrete manufacturing	1	1.01097E-06	5.31616E-07	2.1898E-06	4.01775E-09	3.66899E-10	9.59582E-11	0.000237	9.3819E-07	4.87444E-09	6.83648E-19	7.73984E-14	5.526E-08	2.99463E-07	1.64E-07	7.4678E-07
	Other concrete product manufacturing	1	1.01151E-06	4.24343E-07	2.9471E-06	3.28067E-09	4.64658E-10	2.07105E-10	0.000342	7.61966E-07	1.10814E-08	1.02043E-18	1.17286E-13	1.266E-07	7.04328E-07	3.86E-07	1.75641E-06

A. 5 : Table That Shows Different Indicators Of Materials and The Economic Indicators

	Total Impacts/Impacts from all the other sectors included				ECONOMIC INDICATORS		
		Total demand ($)	Total ($)	Total Intermediate ($)	Import ($M/$)	GOS ($M/$)	GDP (value added) ($M/$)
Cement	Cement manufacturing	1	1.74817E-06	7.48174E-07	8.50812E-08	5.17068E-07	8.90407E-07
Sand	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	1	1.69542E-06	6.95423E-07	6.18597E-08	4.04158E-07	9.19166E-07
Reinforced Steel	Iron and steel mills and ferroalloy manufacturing	1	1.98092E-06	9.80922E-07	1.93366E-07	3.30846E-07	7.46811E-07
	Steel product manufacturing from purchased steel	1	1.98856E-06	9.88563E-07	2.50582E-07	2.59995E-07	7.03144E-07
Water	Water, sewage and other systems	1	1.41701E-06	4.17005E-07	2.78003E-08	5.09213E-07	9.67577E-07
Diesel	Petroleum refineries	1	1.70632E-06	7.06316E-07	5.68869E-07	2.44922E-07	3.99473E-07
Construction Aggregate	Ready-mix concrete manufacturing	1	1.89165E-06	8.91651E-07	1.1005E-07	3.89606E-07	8.44668E-07
	Other concrete product manufacturing	1	1.72321E-06	7.23211E-07	9.65848E-08	3.51039E-07	8.73452E-07

	Direct Impacts/Impacts from only the given sector				ECONOMIC INDICATORS		
		Total demand ($)	Total ($)	Total Intermediate ($)	Import ($M/$)	GOS ($M/$)	GDP (value added) ($M/$)
Cement	Cement manufacturing	1	1.02948E-06	4.61042E-07	3.98472E-08	3.30871E-07	5.26885E-07
Sand	Sand, gravel, clay, and ceramic and refractory minerals mining and quarrying	1	1.01772E-06	4.17058E-07	2.40478E-08	2.40145E-07	5.83927E-07
Reinforced Steel	Iron and steel mills and ferroalloy manufacturing	1	1.07731E-06	6.10186E-07	1.35396E-07	1.16393E-07	3.05116E-07
	Steel product manufacturing from purchased steel	1	1.07235E-06	5.91013E-07	1.79853E-07	6.44771E-08	2.87821E-07
Water	Water, sewage and other systems	1	1.00004E-06	2.67887E-07	9.44286E-09	3.9939E-07	7.35848E-07
Diesel	Petroleum refineries	1	1.07386E-06	4.46039E-07	5.45895E-07	4.27891E-08	7.08278E-08
Construction Aggregate	Ready-mix concrete manufacturing	1	1.01097E-06	5.31616E-07	6.56188E-08	1.56322E-07	3.9774E-07
	Other concrete product manufacturing	1	1.01151E-06	4.24343E-07	5.25783E-08	1.83899E-07	5.29047E-07