LIFE CYCLE ASSESSMENT (LCA) ANALYSIS TOWARDS A SUSTAINABLE CEMENT INDUSTRY FOR SRI LANKA : AN ANALYSIS OF THREE PROCESS PATHWAYS

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(08/8030)

Degree of Master of Science

Department of Chemical and Process Engineering

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Thesis submitted in partial fulfillment of the requirements for the degree Master of Science with major component of research

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“Consumers are increasingly interested in the world behind the product they buy. Life cycle thinking implies that everyone in the whole chain of a product’s life cycle, from cradle to grave, has a responsibility and a role to play, taking into account all the relevant external effects. The impacts of all life cycle stages need to be considered comprehensively when taking informed decisions on production and consumption patterns, policies and management strategies.”

Klaus Toepfer, Former Executive Director, UNEP

Declaration of the candidate & supervisor

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Signature of the Supervisor (Prof Ajith de Alwis) Date

Abstract

Cement has already become an essential commodity which contributes for global development which also contributes globally ~5% of man-made CO_2 as an adverse environmental impact, during its production phase. Cement manufacturers have already implemented programs aiming to reduce their GHG footprint introducing clinker substituted cement types, utilizing alternative fuels and optimizing the cement manufacturing process. LCA is a tool which can be used to quantify & assess the environmental impacts for a selected scope. Study covers a detail LCA study on different cement manufacturing scenarios selecting GHG emission as the main impact category for a local integrated cement manufacturing facility.

As the scope of the LCA 'cradle to gate' approach was selected and functional unit defined as 'one tonne of cementitious material' in order to compare with different clinker percentage cement types. Holcim (Lanka) Ltd – Puttalam Cement Works was selected for the study as the only operating integrated cement manufacturing facility in Sri Lanka. For the scope inland transportation GHG contributions were also included as an extended scope item.

An author designed simple LCA tool 'Cement LCA Calculator' was introduced and used to life cycle inventorying and analyzing process. This tool is compatible with the cement CO_2 protocol published by the WBCSD (World Business Council for Sustainable Development) aligned with GRI (Global Reporting Initiative) & International Panel for Climate Change (IPCC) guidelines.

LCA analysis was categorized into two process units. More than 90% of GHG generated inside the facility due to calcination and kiln fuel combustion in the baseline scenario where no alternative fuels being used. In year 2007 the thermal substitution rate was 19.9% and average overall clinker factor was 76.5%. Also it has been shown the reduction from 913 to 764 net $kgCO_2e$/tonne of cementitious material from the baseline year – 2001 to 2007. Reported neutral absolute CO_2 volumes were 39,940 tonnes in year 2007. However a small increase shown in the local transporting area from 0.56 to 1.31 net $kgCO_2e$/tonne of cementitious material due to increasing alternative fuel transporting activities. The net savings of CO_2 by utilizing waste derived fuels were 3,464 tCO_2e in year 2007 as per the 'Cement LCA Calculator'. Research outcomes also opened a number of LCA based research options as future research areas.

The LCA study has clearly shown the GHG benefits a reduction of 16% by using alternative fuels and clinker substituted products. Both these corporate initiatives are way forward actions towards sustainable cement manufacturing process, which Holcim (Lanka) Ltd is committed by its group strategies. Introduced Cement LCA Calculator can also be used on finding CO_2 minimizing strategies in future cement industry focused ecological improvement studies.

Dedication

To my dearest father

Acknowledgement

I am heartily thankful to my supervisor, Prof Ajith de Alwis, whose encouragement, guidance and support from the initial to the final level enabled me to develop an understanding of the subject.

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I highly extend my gratitude to my work place Holcim (Lanka) Ltd for the given extensive support to initiate this research and carry out it with required resources. Support given by my former supervisors Mr George Nicole, Mr Rathika de Silva are highly appreciated on this regard.

Life Cycle Assessment is still not a popular subject in Sri Lankan context. In order to overcome the faced technical and theoretical constraints given cross boundary support by Dr Rudiger Stenger (Head of Environment) and Dominique Bouchi from Holcim Group Support, Switzerland, Dr. Fredy Dinkel (Carbotech AG in Zurich), Dr. Ir. Joost G. Vogtländer (Associate Professor at the Delft University of Technology) and Dr Rita Schenck (American Center for Life Cycle Assessment - ACLCA) are also highly appreciated.

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Last but not least the support and motivation given by my beloved wife Achala Fernando is highly appreciated. Lastly, I offer my regards and blessings to all of those who supported me in any respect during the completion of the project.

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Abbreviations

Abbreviation	Description
%w/w	Percentage by weight
^0C	Degrees Celsius
ABC	Application based cement
AF	Alternative fuels
Al_2O_3	Aluminum oxide
BDP	Best demonstrated performance
BSEN	British Standard European Norm
BSI	British Standard Institute
CaO	Calcium oxide
cem	Cementitious material
CEMs	Continuous emission monitoring systems
CER	Certified emission reductions
CKD	Cement kiln dust
cli	Clinker
CO_2	Carbon dioxide
COD	Chemical Oxygen demand
CSI	Cement sustainability initiative
EH&S	Environmental, health and safety
EIA	Environmental impact assessment
EP	Electrostatic precipitators
EPL	Environmental protection license
ERP	Enterprise resource planning
Fe_2O_3	Ferric oxide
GDP	Gross domestic product
GHG	Greenhouse gas
GRI	Global reporting initiative
Gt	Gigatonnes
HCl	Hydrogen chloride

HFC	Hydrofluorocarbon
HFO	Heavy furnace oil
HLL	Holcim (Lanka) Ltd
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
K_2O	Potassium oxide
kg	Kilogram
$kgCO_2e$	Kilogram carbon dioxide equivalent
KPI	Key performance indicators
kWh	Kilowatt hour
LCA	Life cycle assessment
LCI	Life cycle inventory
LCIA	Life cycle impact assessment
mg/Nm^3	milligram per normal meter cube
MgO	Magnesium oxide
mins	Minutes
MJ	Mega joule
mm	Millimeter
Mn_2O_3	Manganese oxide
MSDS	Material safety data sheet
N	Newton
Na_2O	Sodium oxide
NIOSH	National institute for occupational health & safety
NO	Nitric oxide
NO_2	Nitrogen dioxide
NOx	Gaseous mixture of NO_2 and NO
OPC	Ordinary Portland cement
P_2O_5	Phosphorus pentoxide
PCW	Puttalam Cement Works
PEP	Plant environmental performance
PFC	Perfluorocarbon
PLC	Portland limestone cement

PM	Particulate matter (dust)
ppm	Parts per million
s	Seconds
SETAC	Society for Environmental Toxicology and Chemistry
SF_6	Sulfur hexafluoride
SiO_2	Silicon dioxide
SLSI	Sri Lanka Standards Institute
SO_2	Sulfur dioxide
t,ton	Metric ton
tCO_2e	Metric ton of carbon dioxide equivalent
TEQ	Toxic equivalent quotient
TiO_2	Titanium oxide
TSP	Total suspended particles
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compounds
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Initiative
wrt	with respect to
YTD	Year to date