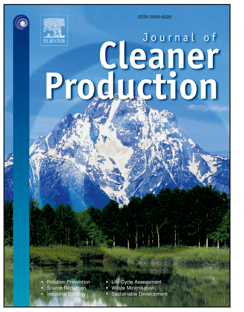
Accepted Manuscript



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PII: S0959-6526(15)00529-6

DOI: 10.1016/j.jclepro.2015.04.136

Reference: JCLP 5505

To appear in: *Journal of Cleaner Production*

Received Date: 27 May 2014

Revised Date: 23 February 2015

Accepted Date: 30 April 2015

Word count: 9623

Effective Carbon Emission Reductions from Using Upgraded Fly Ash in the Cement Industry

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Abstract

Utilisation of supplementary cementitious materials (SCM) has been found as a suitable alternative to reduce CO2 emissions from cement production. Fly ash (FA) is the most well-known of these materials and has been used for decades in cement applications. Amongst these applications, the most significant is the replacement of clinker in cement blends, which reduces the consumption of resources and energy and at the same time, avoids the environmental burden associated with clinker production. Despite the existence of these opportunities, a large fraction of the FA produced worldwide is still unused and disposed as waste or stored in landfills. This occurs mostly because FA is unable to meet the quality requirements for replacing clinker in cement blends. Upgrading of FA to a suitable material that can effectively replace clinker is possible via upgrading processes (UP). These processes carry their own environmental impacts because in most of the cases, thermal and electric energy are used in them. Due to this fact, the use and implementation of upgraded fly ash involves additional environmental impacts to the life-cycle of the product. The most relevant of these impacts during the upgrading stage, is the generation of additional direct and indirect CO2 emissions from energy consumption. From a life-cycle perspective, the generation of these additional CO2 emissions decreases the net abatement achieved by using fly ash as a SCM. Therefore, it is necessary to account these emissions and calculate the net abatement achieved by replacing clinker and fossil fuel consumption.

A system dynamics model is presented by simulating five different cement life-cycle scenarios in order to quantify the net CO2 reductions when using upgrading processes of fly ash. Ultra-fine grinding for the mechanical activation of FA is the UP modelled using published and direct data from the equipment manufacturer. A material flow analysis (MFA) was carried out to describe the scenarios and to simplify the life-cycle approach. It was found that the upgrading process modelled can have maximum value of 3.98 GJ/tonne of fly ash and still be able to produce net reductions. The same model also estimated that an 80% of the total reductions are avoided when ultra-fine grinding consumes 0.75 GJ/tonneFA of energy, compared to emissions from the baseline cement. The model is also complemented by reviewing the current use of FA as a SCM in the cement industry and by presenting a holistic systems thinking analysis. The model can also be further expanded to simulate other life-cycle scenarios which can include multiple upgrading processes and other materials.

1. Introduction

Worldwide demand of cement and concrete has increased exponentially in the last twenty years and is a result of the combination of strong ongoing global trends like the accelerated growth of population, the increased need for buildings and infrastructure and the growth of urban populations relative to rural ones (Ahmaruzzaman, 2010, Gibbs, 2001, Hasanbeigi et al., 2012). Parallel to these trends, developing countries and transition economies have also considerably increased their capability of building new cities and urban settlements, demanding large amounts of construction materials to be continuously available in many places around the world (Dhir, 2006, Foner et al.,