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Review

Low carbon measures for cement plant – a review

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ABSTRACT

Cement manufacturing is an energy and carbon-intensive industry. The cement industry contributes approximately 5% of the global man-made carbon dioxide (CO_2) emissions and is thus becoming the second largest CO_2 contributor in industry after power plants. A wide range of options are available to considerably reduce CO_2 emissions. This paper reviewed major point sources of CO_2 emissions at all stages of cement manufacturing, including (1) raw material preparation (grinding and transportation), (2) clinker production and the combustion of fuels in the kiln and (3) the production of cement final product (milling, blending, mixing, packaging and transportation. Various CO_2 mitigation strategies are subsequently discussed, including (1) energy efficiency improvements; (2) waste heat recovery; (3) the substitution of fossil fuel with renewable energy; (4) the production of low carbon cement by replacing ordinary Portland cement with alternative materials, i.e., geo-polymers, blast furnace slag, coal fly ash, and natural pozzolanic materials; and (5) carbon capture and storage. Although reviewed CO_2 mitigation measures are indeed beneficial to the environment, however, they are also bounded by some limitations. The limitations and selection of CO_2 mitigation measure are also outlined in this paper.

1. Introduction

Cements are finely powdered substances that possess strong adhesive abilities when mixed with water. Due to the importance of construction and abundance of raw materials, the level of cement production is high (Hendriks et al., 2004). However, cement production is recorded to have released approximately 5% of the current global man-made carbon or carbon dioxide (CO_2) emissions (Stefanović et al., 2010). These carbon emissions originate from the burning of fossil fuels in kilns; electricity use from grinding raw and finished materials; and the clinkerisation process of the main raw material, such as limestone (Hendriks et al., 2004).

Therefore, the cement industry is currently deeply committed to reduce emissions and other environmental impacts that arise during the cement manufacturing process. Diverse solutions to reduce the carbon footprint of cement plants have been previously investigated in various studies. Some of these studies included improvements in energy efficiency (Ali et al., 2011; Madlool et al., 2013), waste heat recovery (Benhelal et al., 2012; Saneipoor et al., 2011), the substitution of fossil fuel with renewable energy (Kookos et al., 2011; Schuhmacher et al., 2009), the production of blended cement or geo-polymer cement (Sarker et al., 2013; Temuujin et al., 2010) and carbon capture and storage (IEA, 2009).

A number of reviews have centred on carbon mitigation; one such recent review on CO_2 abatement can be found in Benhelal et al. (2013). Their review discussed CO_2 mitigation for CO_2 processes only. However, the production of low-carbon cement by using alternative binders, such as geo-polymer, blast furnace slag, coal fly ash, and natural pozzolanic materials, has been proven to significantly reduce CO_2 emissions. These processes were not addressed in the aforementioned review. This review comprehensively discusses sources of CO_2 emissions and mitigation strategies for cement manufacturing for processes (e.g., clinker production and fuel combustion in kiln) that consume energy and electricity-related emissions from milling, grinding, transportation of raw materials and the cement final products.

1.1. Overview of general cement production process

Four common processes that are part cement manufacturing are dry, wet, semi-wet and semi-dry processes (Mohanty, 1997). Fig. 1 shows the general cement manufacturing process for both dry and wet processes.

The figure indicates that cement manufacturing processes begin with the following steps:

1.1.1. Raw meal preparation

Raw meal preparation is a process that covers the quarrying of raw meals that are subsequently fed to the kiln or pre-heater.

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