SOLPART

High Temperature Solar-Heated Reactors for Industrial Production of Reactive Particulates

European funded project - Grant Agreement number 654663

Deliverable 6.2

WP6 – Environmental life cycle assessment of the solar process and comparison to the standard technology

Deliverable D6.2 LCA of the standard technology and comparison to SOLPART

Date of Delivery:

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1 Introduction

Worldwide production of cement surpassed 4.65 billion tonnes per year, making cement industry one of the most significant manufactures in the world (CEMBUREAU, 2017). About 7% of the total anthropogenic CO_2 emissions (about 1.47 Gt CO_2 per year) have been attributed to the cement industry (Ruan and Unluer, 2016). A large amount of those CO_2 emissions are caused by the combustion of fuels (41%), which are utilized to provide the thermal energy for the decarbonisation and sintering of cement raw meal as part of cement production (Benhelal et al., 2013).

The SOLPART project investigates the use of solar thermal energy for the calcination of limestone as part of the cement production process in attempt to reduce fuel related CO_2 emissions. The scope of this project includes experimental investigation of the performances of the solar reactor at different scales (WPs 2 and 5), its integration in a full-scale cement plant (WP 7) and the Life cycle assessment (LCA) of the SOLPART system.

LCA is a standardized method used to quantify the environmental impact of products and services for both commercial scale and emerging technologies (ISO, 2006, Lacirignola et al., 2017, Cucurachi et al., 2018). Moreover, this methodology has been widely applied by the cement industry to assess the impacts of cement production process and of possible improvements, such as the use of alternative fuels (Stafford et al., 2016, Holt and Berge, 2018).

Thus, this report presents the life cycle assessment (LCA) of the conventional cement production technology and a comparison of its impacts with those of the SOLPART cement plants as described in WP 7.1. Therefore, the environmental impact of SOLPART cement plants of capacity of 3,500, 1,000 and 500 t of calcined material per day (equivalent to 4,683, 1,338 and 669 t of cement per day) have been considered for this assessment. Moreover, further improvements for the cement production system, including the use of 100% alternative fuels (municipal solid waste, waste oils, solvents and tyres) for the clinkerisation of calcined cement raw meal, the use of renewable electricity and the carbon capture are also assessed.

2 Conclusions

This study quantified the potential life cycle environmental impacts of cement production using solar thermal power to calcine raw materials in comparison to the conventional process. For solar systems, two types of reactors, fluidised bed and kiln, were considered along with three different cement plant capacities producing 3,500, 1,000 and 500 t of clinker per day. In all the scenarios considered, the largest SOLPART plants (3,500 tpd) had the lowest impacts, while 1,000 tpd plants had the highest impacts due to the design configuration which had a higher number of heliostats.

The results also show that, compared to the conventional cement, SOLPART cement has 44% lower GWP due to the lower fuels requirements. Similarly, reductions are observed in human toxicity and eco-toxicity impacts (29-59%) due to the lower amounts of pollutants released by the system. The resource depletion-energy is also 12% lower for the SOLPART cement due to the lower fuel requirements.

Compared to the conventional system, the SOLPART cement production increases impacts in four categories, namely freshwater eutrophication (5%), land use (44%), resources depletion-metals (2%) and water (7%). These are mainly related to the impacts of the construction of solar field due to the large number of heliostats (4910 for 3,500 tpd plant).

It worth highlighting that due to large land requirements for the solar calciner, the land availability and the insolation level of the area considered might be limiting factors for the development of this technology. Therefore, locations specific case studies are necessary to investigate the techno-economic feasibility of the SOLPART system in locations of interest. Moreover, further research aimed at reducing the size of the solar field is necessary to increase the applicability of this technology.

From the sensitivity analyses it emerged that it might be possible to reduce further the impacts of the SOLPART cement plant by utilising 100% MSW as fuel for clinkerisation. However, the feasibility of such system and drawbacks related to the formations of large amounts of halogenated compounds and the emissions of various pollutants should be carefully considered.

Furthermore, most of environmental the impacts of cement production can be further reduced by utilising electricity from renewable sources (such as PV) for the whole cement plant. However, the additional land required for the installation of the PV field can be a limiting factor.

Adding CCS to the conventional cement plant could reduce the GWP of cement production by 57%, against the 44% estimated for the SOLPART system. However, due to the additional fuel needs, all other environmental impacts increase significantly with CCS. The LCA results show that CCS has 41-94% higher impacts in 13 out of 16 impacts categories compared to the SOLPART cement. However, CCS has lower land requirements and metals depletion. Flue gases produced by the solar calciner potentially contain larger concentration of CO_2 compared to those of conventional calciner. This is because in the

SOLPART system hot air produced by the kiln and by the cooling of clinker is sent to the preheater directly, avoiding dilution of the CO_2 produced by limestone calcination. Due to this reason, flue gases released by the solar calciner contain less contaminants compared to the stack emissions of a conventional cement plant. Thus, it might be possible to reduce the amounts of material and energy required by selectively treating exhaust gases produced by the solar calciner. Coupling CCS and the SOLPART system shows the potential to reduce the emissions of the cement production process by up to 73%. However, additional capital and operating costs related to CCS should be evaluated carefully and compared to those of the SOLPART system.

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