Improving cement carbon footprint through increased alternative fuels and raw materials utilization

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Achieving carbon neutrality in the cement and concrete value chain by 2050 in line with the decarbonization roadmaps of the sector and EU circular economy principles, requires the implementation of intensive carbon dioxide mitigation strategies. A key lever towards a net zero path is the increased utilization of alternative fuels (AF) and alternative raw materials (ARM) which are derived from waste streams of industrial, municipal and commercial activities. When appropriately processed and quality checked, they can replace non-renewable carbon intensive conventional fuels and quarried raw materials used in the cement production. This also leads to a notable diversion of these waste streams ending up in landfills, that would, otherwise, have been handled as waste and would have been landfilled, with subsequent associated impacts to the local environment, land, water resources, and ecosystems.

In this work, the impact of using AF and ARM on the carbon footprint of cement throughout its life cycle (cradle-to-gate) was evaluated by adopting different utilization scenarios and implementing a Life Cycle Analysis (LCA). The LCA is performed according to ISO 14040 and ISO 14044 (Finkbeiner et al. 2006) in four cement types of varied clinker content as produced in Titan's plants in Greece (Kamari, Thessaloniki, Patras). In particular, the pre-verified "Industry EPD Tool for Cement and Concrete" (v4.2) by the Global Cement and Concrete Association was used which incorporates the life cycle inventory database ecoinvent (v3.5).

Various combinations of fossil and AF ratios (primarily SRF derived from non-hazardous solid waste), were investigated. Each fuel mix exhibited different biomass content, the ones rich in SRF possessing the maximum value. On the other hand, ARM used were partly "decarbonized", which means that they contain calcium oxide in non-carbonated form, thus can partially replace some of the limestone in the raw meal, without releasing CO_2 during their calcination. In our study, the use of electric arc furnace slag (EAFS), ladle furnace slag (LFS) and granulated blast furnace slag (GBFS), was evaluated, all being wastes from steel production.

Figures 1 and 2 denote the Global Warming Potential (GWP) expressed in kg CO_2 eq. per plant and per type of cement, with respect to thermal substitution rate (%TSR) and ARM participation rate (%ARM). GWP is defined according to the Intergovernmental Panel on Climate Change (IPCC), as an index measuring the impact of a gas on atmospheric warming over a 100-year period compared to carbon dioxide.

Alternative fuels

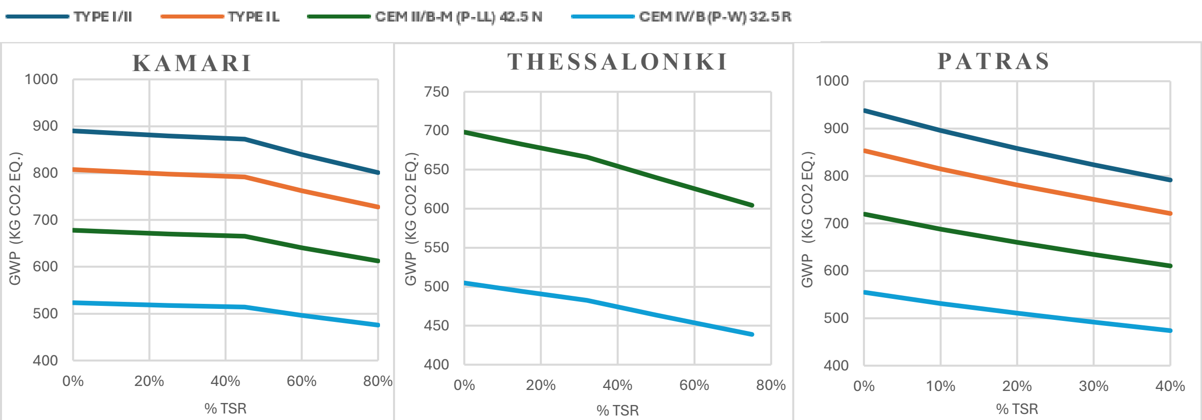

Figure 1 GWP vs %TSR for Kamari (left), Thessaloniki (center) and Patras (right) plants.

It is evident that the use of AF has significant effect in improving the carbon footprint of each cement type, and especially those with higher clinker content (ASTM Type I/II and Type IL). This leads to savings in CO_2 eq. per cement type up to 9-10% for Kamari, 13.3% for Thessaloniki and 15.2% for Patras for the scenarios with the maximum %TSR. This is obviously related to the highest biomass content in the fuel mix which is increasing with the participation of the AF. The Kamari plant exhibits a more notable reduction for TSR above 45%, which is technically feasible due to the new pre-calciner technology (investment) recently installed.

Alternative raw materials

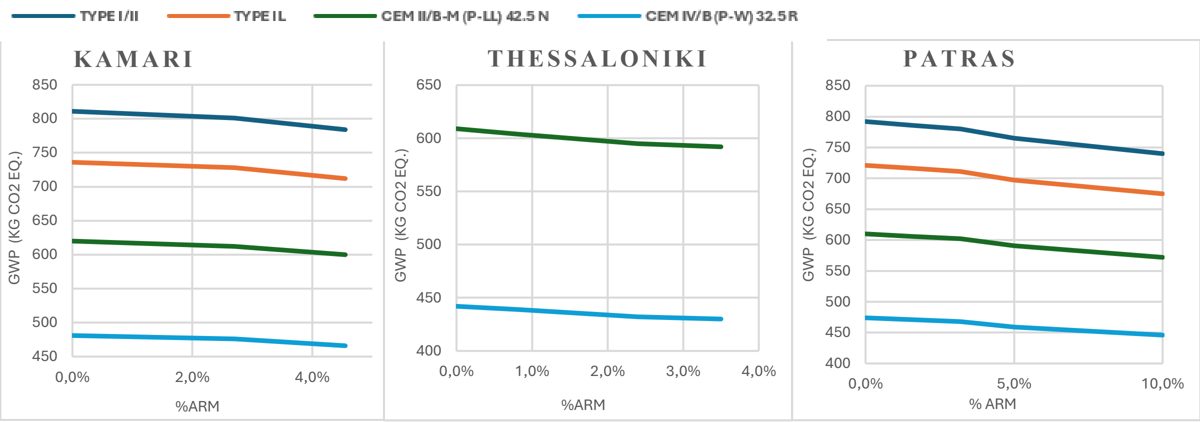

Figure 2 GWP vs %ARM for Kamari (left), Thessaloniki (center) and Patras (right) plants.

The ARM scenarios are based on the LCA of the clinker for the maximum %TSR per plant. The participation reaches a limit between 3.5% and 4.5% for Thessaloniki and Kamari plants respectively due to the quality restraints of the cement clinker raw meal and the availability of the materials. For the maximum rate of ARM, approximately 3% CO_2 eq. per cement type is avoided due to equivalent limestone substitution, which is attributed to the calcium oxide that ARM contain in non-carbonated form. With regards to Patras plant, a 10% substitution in the case of GBFS seems feasible which corresponds to CO_2 eq. savings almost up to 6%.

Conclusions

The utilization of alternative fuels and alternative raw materials contributes to climate change mitigation and simultaneously to waste valorization, showcasing a good example of industrial symbiosis.

By adopting an LCA to measure the carbon footprint of various types of cement, and testing combined utilization scenarios of AF and ARM in different plants of Titan Greece, it was demonstrated that a good comparative estimation of the GWP, hence CO_2 eq. saving, is achieved.

The CO_2 emissions reduction varies according to each plant's process and quality constraints, technology and material availability, cost, and logistics. The combination of both examined alternative sources can enhance each plant's efforts for decarbonization through recycling or recovering of materials and energy to preserve natural resources and support the circular economy. Indicatively, a maximum CO_2 eq. avoidance up to 21% seems feasible with the use of 40% TSR and 10% ARM in the Patras plant.

Along with other levers of decarbonization, such as the reduction of the clinker to cement ratio in the cement portfolio, the maximized use of AF and ARM can also play a notable role in the design and development of low-carbon cement products to address the current and future needs of the customers for lower carbon construction solutions.

References

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