TOWARDS ZERO CARBON FUELS FOR CEMENT MANUFACTURE

In many countries, cement manufacturers have already made considerable investments in fuel switching from conventional coal and petcoke to alternative fuels. Indeed, the cement industry uses alternative fuels from waste through a combination of both material recycling and energy recovery (referred to as co-processing). Today, alternative fuels including waste biomass account for 44% of cement industry fuel mix (Get the Numbers Right (GNR) project 2016). In line with our Low Carbon Roadmap, the aim is to take this up to 60% by 2050. This would lead to a 27% reduction in fuel CO_2 emissions.

To achieve deep levels of decarbonisation in cement manufacture it will be necessary to provide some of the combustion energy needed to drive the chemical reactions in the kiln from both tradition and 'novel' carbon neutral or near zero emission sources. This paper provides a brief overview of existing and potential longer-term solutions.

Alternative fuels and co-processing

Co-processing is the combination of simultaneous material recycling and energy recovery from waste in a thermal process. As it combines energy recovery and material recycling, it forms an industrial response to the circular economy principles. By using waste as a fuel, the cement industry also contributes towards the security of energy supply. The cement industry uses waste which is, in principle, non-recyclable due to a number of factors, including:

- Recycling is not always economically viable
- There can be an insufficient market for the recycled product
- Recycling could, in fact, not be the best ecological option (e.g. by increasing the CO_2 footprint)

Currently, there is no technical limitation at the cement plants to increase the share of alternative fuels up to 95%. Reaching this level will be highly dependent on the existence and implementation of adequate regulatory conditions, the correct pre-treatment of waste streams and the existence of an economic level playing field to access waste streams.

According to the ECOFYS study "Status and prospects of co-processing of waste in EU cement plants" dated April 2017, if the alternative fuels rate in the EU-28 will increase from 44% to 60%, this will result to expenditures savings in additional waste to energy plants up to 12.2 billion Euro and emissions avoidance of 26.0 Mtonnes of CO_2 per year.

The main drivers for co-processing are: incentives for separate waste collection, applying landfilling ban in all EU Member States and low bureaucracy for issuing permits for usage of waste for kilns.

Additionally, the potential of co-processing can be enhanced further through legislative and regulatory measures that recognise this form of material recycling and its contribution towards achieving Europe's ambitious recycling targets.

Biomass

Waste biomass use in cement manufacture is a fantastic example of the circular economy in action. Biomass that cannot be economically recycled in other operations can be recycled using the cement industry's unique 'co-processing' operation. The use of waste biomass, that has already been used at least once for another purpose and reached the lowest point in its value chain, ensures that its energy/mineral content is recycled in cement product, effectively restarting a value chain.

Waste biomass will continue to be a valuable part of the cement kiln fuel mix for the foreseeable future. However, it comes with technical and market limitations that restrict biomass fuels being used for all of the kiln combustion heat demand:

- First and foremost, there are significant uncertainties in terms of availability for industrial thermal uses. Biomass fuel sources are limited in supply due to a number of factors including land area availability, improved recycling processes, demands from waste to energy plants and quality issues (e.g. glues and preservatives on structural timber). Consequently, biomass only provides a partial solution for cement kilns.
- 100% biomass fuels, e.g. from timber production and use, also have their advantages and disadvantages. Natural woods tend to have a high moisture content and therefore provide lower calorific input than traditional fuels. There have also been questions raised over the sustainability credentials of wood fuels produced solely for power generation.
- Waste woods can be environmentally problematic where they are treated with paints, varnishes, glues and preservatives. There is an increasing trend of glued woods entering the construction supply chain which could be storing up a waste disposal problem for the future. The presence of trace elements is also problematic at high levels of replacement.

Despite the limitations associated with the use of waste biomass, natural tree-based biomass and waste woods, it will remain part of the solution for the cement sector. Furthermore, it is also important to recognise that these natural sources of energy, when combined with carbon capture technologies on the cement kiln, could potentially provide a 'net-negative' carbon footprint.

Used tyres are an example of a type of waste which can be recycled, but for which there is insufficient demand for the recycled product. It should be noted that tyres contain a significant amount of biogenic carbon (about 27% due to the content of natural rubber), thus leading to a direct reduction of fossil fuel-related CO_2 emissions. The cement production process offers the possibility of simultaneous energy recovery and material recycling of the individual components of the tyre. Used tyres have a high calorific value, which makes them an ideal fuel for the cement industry. At the same time, they have a high iron and silica content which makes them perfect for material recycling, allowing the cement industry to reduce its consumption of primary raw materials.

Sewage sludge is also a good example of a biomass fuel which can be used as both an alternative fuel and raw material in the clinker manufacturing process. Sewage sludge has relatively high net calorific value, as well as lower carbon dioxide emissions factor compared to coal when treated in a cement kiln. Use of sludge in cement kilns can also tackle the problem of safe and eco-friendly disposal of sewage sludge. Due to the high temperature in the kiln, the organic content of the sewage sludge will be completely destroyed whereas the sludge minerals will be bound in the clinker after the burning process.

Electrification

As the power grid decarbonises renewable/low carbon electricity may in the future provide a potential but technically challenging opportunity for the provision of kiln heat. When operated on traditional fuels the cement kiln system utilises a flame temperature of around 2000°C to drive a reaction requiring at least 1450°C. Important characteristics in the kiln include the length of the flame, its temperature and how it transfers heat to the raw materials. Decarbonised power could theoretically be used to create electromagnetically generated plasma. Although there are no current examples of plasma technology being used for cement manufacture there are parallels that can be drawn from the waste treatment sector which has examples of plasma technology in operation. The amount of electricity needed (estimated at ~300MWe for an average kiln), its cost and the technical unknown for such a new type of kiln design currently form is being researched by the industry.

Hydrogen

In a fully decarbonised future, and bearing in mind that the full potential of natural gas has not yet been exploited and can still lead to considerable savings in CO_2 emissions, hydrogen is one of the candidate gases that could be used to replace or partially replace natural gas in the network. There are a number of types of hydrogen (blue, grey, green) that have been categorised on the basis of the environmental credentials of the different production processes. Green hydrogen utilises renewable electricity and the hydrogen could potentially be used as a combustion fuel in the cement kiln without the resultant CO_2 emissions associated with traditional fuels and biomass.

This is, of course, reliant on the availability of renewable energy in sufficient quantities and associated colossal investments to transform both energy and industrial assets. Indeed, hydrogen has not been tested in the cement manufacturing process and its properties mean that it could only partially replace the traditional fuel requirement. Hydrogen use may affect the physical aspects of the kiln system, the fuel mass flows, temperature profile, heat transfer and the safety considerations for the plant. A feasibility study is underway to establish the prospects of partial hydrogen use in a cement kiln system.

Fuel Looping

'Fuel looping' is a shorthand description for using the products of combustion to create new fuels. These technologies such as methane/methanol production using CO_2 and hydrogen or utilising CO_2 to promote algal growth to produce biomass or bioliquids, require carbon capture to be fitted to the cement kiln. These technologies represent 'temporary' carbon storage until utilised as fuel. When operated in a loop system these CO_2 utilisation technologies represent an interesting and further example of the circular economy benefits of cement production and the versatility of the cement process. Algal growth has already been researched by a number of cement companies.

Conclusions

Using a combination of carbon neutral and near-zero emission energy sources for the combustion process of the kiln could reduce the total emissions from cement manufacture by around 40% compared to a traditional solid fuel equivalent. The technological barriers are high and the cost barriers potentially higher. The industry is actively researching these 'novel' fuel methods as part of its commitment to decarbonisation. There however will also be an increased demand for biomass going forward in other industry sectors such as a fuel for power generation and as a feedstock for the chemicals industry.