IDV.7.3: Alternative feedstocks to promote bio-based and circular economy in industrial intensive sectors: the RETROFEED project approach

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ABSTRACT: European countries depend highly on the feedstock import markets which are progressively becoming more variable and unstable. The RETROFEED project will promote a more robust and sustainable value chain incorporating the alternative feedstock in the Resource and Energy Intensive Industries (REIIs). The present study has contemplated the current feedstock to be partially or totally replaced and the alternative feedstock or internal waste to be considered according to quality requirements, market availability, and competitive pricing. While the ceramic sector has centred its effort on the re-use of internal process waste, the aluminium sector, has focused on the introduction of a wider range of recycled raw material. The cement sector, on the other hand, has explored prospective alternatives feedstock for energy production, among which biomass and refused derived fuels can be highlighted. The steel sector intends to curtail fossil fuel dependency through employing biochar and polymeric-derived residues, such as plastic and rubber. Finally, the agrochemical sector plans to partially replace their main phosphorous source by more sustainable materials, such as ashes derived from biomass combustion and organic wastes.

1 INTRODUCTION

The raw materials supply in the European Union (EU) has been increasingly addressed during the last years due to the high dependency on the external resources [1,2]. Thus, European Commission (EC) has promoted diverse policies to warrant the feasible access to the feedstocks in a sustainable, reliable and efficient supply chain without compromising the industrial competitiveness and economy growth [1]. To this regard, EC has been focused on the generation of alliances and strategic partnerships and legal framework, and the deployment of circular economy strategies [1,2].

The Resources and Energy Intensive Industries (REIIs) are currently involved in the transformation of the production chain boosted by the EC support in order to attain climate-neutrality by 2050 [3]. In addition, one of the major priority of the EC to this concern is the promotion of a sustainable growth considering resource efficiency, greener and more competitive economy [4]. In this framework, RETROFEED project will aid to incorporate the use of alternative feedstock within the productive process in the REIIs. Particully, in five different sectors: ceramic, cement aluminium, steel and agrochemicals.

2 METHODOLOGY

For assessing the use of alternative feedstock, the following methodology has been applied:

a) Identification of the current situation of the industrial intensive sector and the current feedstock interest to replace partially or totally.
b) Identification of the new alternative feedstock or internal waste to be incorporated in the process.
c) Evaluation of the resources availability in the surrounding area, the necessity to implement a new logistic chain or possibility to directly purchase from a particular supplier.
d) Estimation of the economic feasibility and evaluation of the advantages and challenges to be faced.

3 CURRENT SITUATIONS

3.1 Ceramic sector

The ceramic industry is a major consumer of industrial minerals (quartz, kaolinite, aluminum oxide, titanium oxide, feldspar, zinc oxide, barium carbonate, borax, boric acid, zirconium silicate, calcium carbonate, lithium feldspar, dolomite, clay) around the world, every year, millions of tons of raw materials are used in several segments to produce the most diverse ceramic products. There are growing concerns over the availability of secure and adequate supplies of the material of the ceramic sector, since many of them are part of the list of Critical Raw Materials consolidated by the European Commission [5].

Finding raw material substitutes for the ceramic sector it was not the goal in RETROFEED project, however it was to recycle a considerable portion of the internally generated waste frit, to cut back on raw materials consumption, reducing waste and optimizing energy uses.

Waste frit is produced as a result of unavoidable remnant quantities of preceding formulations in the furnace and associated pipping.

3.2 Cement sector

Fossil fuel-based carbon is widely used in the cement industry in a number of forms, for instance petcoke, fluid coke and fuel. According to Statista [6], the revenue of manufacture of coke and refined petroleum products in Portugal (where the demo site is located) will amount to approximately 1,385 million U.S. Dollars by 2023, which is almost half of the current 2020 values.

One of the main goals of the demo industrial intensive company of the cement sector inside of RETROFEED projet is the partial replacement of the petcoke used as energy source for the kiln with an alternative feedstock in order to decarbonize their plant. In this sense, this industry wishes to replace between 60-80 % of the thermal energy by introducing sustainable alternative feedstock fuels in their process.

For this purpose, three types of alternative feedstock have been identified as potential options for achieve their purposes: biomass, tires and refused derived fuel (RDF).

3.3 Aluminum sector

One of the main objectives of the industrial intensive demo-site studied inside the aluminum sector is to increase the share of contaminated scraps (paints, oils > 10 %) in order to reduce the dependency of aluminum material and at the same time contribute to the circular economy objectives of this sector.

In order to achieve this goal, they are considering to use painted scrap, taking into account a pre-treatment process required to be environmentally sustainable.

3.4 Steel sector

Steel sector is focused on the reduction of its reliance on fossil fuels, in order to lower the CO_2 footprint and achieve the EU targets for lowering greenhouse gas emissions and to promote the circular economy and reduce dependence on feedstock from other countries.

Currently natural gas and anthracite are used as a source of energy in its Electric Arc Furnace (EAF) process. Here it is important to mention that carbon is used as stoichiometric agent in the melting process, being difficult to reduce the CO_2 emission from the steel industry due to this reason.

Steel sector is currently busy working out in different alternative feedstock that could be suitable for their requirements as biochar (with high content of C), waste plastic grains and rubber.

3.5 Agrochemical sector

Currently, the production of fertilisers consumes a large amount of energy [7] because they are generated from energy-intensive processes such as Haber-Bosh process used for production of nitrogen fertilisers. The use of chemical fertilisers in the EU in 2010 was 10.4 Mt of nitrogen, 2.4 Mt of P_2O_5, and 2.7 Mt of K_2O. Between 2019 and 2020, it is expected to reach 10.8 Mt, 2,7 Mt and 3,2 Mt, respectively.

Each fertiliser has a characteristic composition in terms of raw materials inputs and its utilisation rate. The sources of raw materials entail high composition costs as a result of transportation and associated geopolitical problems, due to the dependence of these minerals (such as phosphate rock and potash) from other countries.

In this way, the agrochemical sector, focuses its innovation activities on the implementation and integration of the NPK fertiliser though other process with other alternative raw materials, such as the use of ashes resulting from biomass incineration and food production waste from nearby producers as a source of phosphorous and potassium, and the combination of products obtained from wastewater treatment units with other product from nearby units (struvite and digestate).

4 PROSPECTS OF THE INDUSTRIAL USE OF ALTERNATIVE FEEDSTOCK AND INTERNAL WASTE.

4.1 Ceramic sector:

4.1.1 Recycle glass culets

Waste glass is an important input material for ceramic process. An important aspect to be considered is that the contamination by amber coloured glass ampoules have to be avoided. The use is limited to the Na_2O and B_2O_3 oxide content in the frit.

Waste glass is produced by several types of industries (food & beverage, automotive, scraps from glass products manufacturing, etc.) and by residential users (packaging waste glass).

According to Eurostat values [8], the EU market price for waste glass was around 52-57 €/t in 2020, slightly higher than the 53 €/t average value for 2019; over the last five years, it varied in the range between 45 and 58 €/t.

4.1.2 Recycled fly ashes

In some cases, fly ashes have been used and recycled in melting process, as ZnO source. Use is limited to the content of impurities like Cl, S. More information about ashes can be found in section 4.5.1.

4.1.3 Prospects of internal waste

The two main waste materials generated during the frit production process are studied has alternative materials: calcium concentrated brine and waste frits.

Out of the two main waste materials, the former is related to calcium-concentrated brine generated in the water softening process needed to pre-treat water fed to quench the molten frit. Water is demineralised using a resin-based ion-exchange water softener, where calcium ions are replaced with sodium ions that are characterised by a lower tendency to scaling, thus producing as residue the above-mentioned calcium-concentrated brine.

Waste frit is generated when a new composition is required for the frit and therefore a new recipe is charged on the material feeding system to the smelters.

The current fate of the material is to be chemically checked, spray-dried and milled to produce a powder with homogeneous composition ready for recycling as input material for new frits with the same characteristics. However, this introduces additional energy consumptions, related both to the process needed to convert input materials into frit and to the post-processing of the waste frit to produce material suitable for re-use.

Therefore, although not allowing material savings - since even in the current configuration of the plant all waste frits are recovered in the production process - the minimisation of the amount of waste frit is an important objective for the plant since it allows energy savings (savings related to the avoided energy consumption for waste frit production and subsequent drying and milling), environmental and economic benefits. In order to achieve this objective, both an optimisation of production planning - with the aim of minimising the number of frit changes - and an optimisation of process management - with the aim of minimising the quantity of waste frit produced per frit change - shall be carried out.

4.2 Cement sector

The cement sector does see itself as being part of the bio-based economy. This study provides the potential for using biomass, RDF and tires as alternative feedstocks.

4.2.1 Biomass as an alternative feedstock

In order to fulfil the goal of 60-80 % of the thermal energy substitution, an interesting alternative fuel is the use of biomass. Assuming a LHV of 4.5 kWh/kg of biomass (this number can change considerably depending on the type of biomass and the moisture content), the estimated biomass quantities that a corporation around 19,000 MWh/year potentially needs to achieve this goal is between 4,000 tonnes/year (with a moisture content lower than 15 %). To compute these amounts, thermal energy substitution targets have been considered, and it has been assumed that other feedstocks would also be employed to cover this percentage.

Biomass is a valuable resource for producing bioenergy minimizing greenhouse gas emissions. The following biomass resources have been examples of identification: agricultural residues (from annual crops: such as straw and maise /sunflower stalks from rainfed and irrigated lands; from orchards / permanent crops: vineyard, fruit and olive tree pruning wood), forestry residues (such as treetops and branches produced in timber exploitations and silvicultural works in forests of broadleaved, evergreen and mixed forests). Some of the main characteristics to be considered for each source of biomass, are:

-Herbaceous material: the average price is usually between 40-50 €/t, moisture is lower than 15 %, and the average LHV (low heating value) is between 4 and 4.3 kWh/kg (at 10-15 % of moisture). In this case a low pre-treatment cost is required.

-Woody agricultural pruning (olive, vineyards, fruits and others): the average price is usually between 40-60 €/t (depends on size distribution and moisture content), moisture is around 30 %, and average LHV is between 3.3 kWh/kg (at 30 % of moisture) and 4.5 kWh/kg (at 10 % of moisture). In this case, a medium pre-treatment cost is required.

-Forestry wood logs: the average price is usually between 65-85 €/t (moisture 30 %, supply format G-30/40; price when distributed in large amounts). There is the possibility of receiving sets of wood from fires or whole trees. In that cases the price is lower, although the features as fuel are also worse; moisture is around 30-35 %; and average LHV is between 3.6 kWh/kg (at 30 % of moisture) and 4.7 kWh/kg (at 10-15 % of moisture). This type of biomass needs a high pre-treatment cost.

-Forestry wood residues: the average price estimation is around 50-70 €/t, moisture is about 30-35 % (it will be extremely dependent on the practice of the new chain that could be implemented, mainly on the time that could remain in the forest before its collection) and average LHV is among 3.3 kWh/kg (at 30 % of moisture) and 4.4 kWh/kg (at 10-15 % of moisture). In this case, a high pre-treatment cost is required.

4.2.2 Other alternative biomass resources

Besides the biomasses previously mentioned, other alternative biomass as residues from agro-industrial processes such as olive cake, sawdust, almond shell, grape seed flour, etc. should be considered as potential supply sources.

Some of the associated advantages to employing these biomass sources are the current market and a distribution biomass supply chain. Its potential availability depends on the demand of each of these biomasses. An industry around 19,000 MWh/year requires approximately 4 kt/year, which could be achieved with some of these agro-industrial residues. In general, their size distribution is small and if the industry wants to reduce the format through a hammer mill, the energy cost normally is lower than with other agricultural and forest biomass resources. The moisture content normally is lower than 15 %, which means the corporation would not have to incur in drying expenses and the price is more competitive than with forestry woodchips.

The following information depicts the principal characteristics of some biomass coming from residues of agro-industrial processes:

-Olive cake: in recent years the price dropped below 40 €/t (even lower with prices of 15 €/t at the exit of the olive pomace oil extraction industry), moisture is lower than 15 %, and average LHV is around 4.2 kWh/kg (at 15 % of moisture).

-Almond shell: the average price is usually between 55-70 €/t (not grinded), moisture is around 15 %, and average LHV is about 4.4 kWh/kg (at 15 % moisture). Low pre-treatment cost is required.

-Grape seed flour: the average price is usually between 65-85 €/t; moisture is around 15 %, and average LHV is about 4.5 kWh/kg (at 15 % moisture). Low pre-treatment cost is required.

4.2.3 Refuse Derived Fuel

Some industries have been using “Refuse Derived Fuel” (RDF) in their installation for several years, with a large portion of the thermal energy demand currently being covered by this fuel.

This fuel began being used in the early 90s industry; looking at the possibility of reducing energy-associated costs, the cement industry among other sectors, took interest in using fuels derived from waste. When it was not possible to identify these fuels as a “mono-stream”, i.e., a fuel with a unique chemical composition and precedence such as tires, wood, they were grouped under RDF denomination. Further to the growing interest in waste derived fuels, waste management companies started to generate some types of “fuel” or RDF.

Some of the main types of wastes from which RDF are produced are remaining fraction of municipal waste, non-hazardous industrial waste, bulky waste (such as discarded furniture), waste coming from plants of waste.

Since the material is heterogeneous, the final users normally have to carry out periodical analysis of this RDF in order to assess quality for being used in their installations. For this reason, European standard EN 15359 was elaborated to standardise the fuel properties of this waste, and instead of being called RDF, it was referred to as solid recovered fuel (SRF). The main goal of this standard is to help facilitate the SRF acceptance among the final users.

A recent ERFO study (2015) has investigated the use of SRF in the EU per application. This study concludes that the best and most reliable data available comes from cement kilns and dedicated SRF/RDF waste-to-energy plants. These two are currently the biggest markets for SRF/RDF. SRF/RDF are also used in power plants, gasification/pyrolysis, industrial plants, blast furnaces and others, such as lime kilns. Data regarding these other uses are considered as less reliable [9].

Based on assumptions for yearly production and waste management of MSW, C&IW and C&DW, reported in the previous study from ERFO and Cembreau, they estimated that there is a potential production of approximately 63 Mton/y of SRF/RDF in Europe. Concerning the demand, other than the cement industry that remains the most relevant European market (a potential for substitution of 40% is assumed), the report identified a number of industrial sectors with a higher potential for the use of SRF/RDF as fossil fuel substitute. These sectors were, paper and chemical industry, (potential for substitution of about 5 %), power generation plants and co-combustion with biomass (potential for substitution of about 2 %), district heating systems (potential for substitution of about 3 %).

A total prospective demand of SRF/RDF around 50 Mton/y was assumed by ERFO and Cembreau, mainly coming from the cement industry, while the above-mentioned industrial sectors can contribute up to 12 Mton/y.

According to data reported in 2020 by the IEA task 36 [10], Germany, the United Kingdom, Italy and the Netherlands are the main producers of RDF in Europe. However, the market flows of the RDF taking into account exportation and importation take place over all the continents. Export from UK is most dominant, but there are a lot of other cross border flows as well price of RDF/SRF.

Regarding prices, the preparation of RDF incurs a cost of about 10-20 €/t to cover sorting, baling, wrapping, etc. The higher the number of pretreatment steps required, the higher the cost. The web Lets recycle [11] gives a price indicator of the market of the RDF: These numbers are similar to the ones reported in The International W2E Market Bulletin [12].

4.2.4 Waste tires

Another opportunity is related to the use of waste tires as input materials. Due to the vulcanising process that they undergo, it is difficult to recycle them through standard methods for thermoplastic materials. Therefore, one of the main processing activities carried out for waste tires implies grinding (if needed) and use in processes like asphalt production.

According to the European Tyre Recycling Association, the recovery rate of end-of-life tyres in the EU is on average of 96 %, with some Member States reaching 100 % recovery in energy or material terms, with landfilling reduced to very low levels compared to the 25% recorded in 2004. Specifically, according to the European Tyre & Rubber Manufacturers Association, in 2016 in the EU28, 117,000 tons of end-of-life tires were used for civil engineering, public works and backfilling; 1,630,250 tons were recycled; 999,750 tons went to energy recovery; 160,000 tons were landfilled or ended unknown; 561,000 tons of part-worn tires were re-traded, reused or exported.

4.3 Aluminum sector

4.3.1 Painted Scraps

The input used in a plant for aluminium production is constituted by scraps of different types. The potential opportunity for a higher exploitation of circular feedstocks is related to the increase of the fraction of scraps and to the increased use of low-grade scraps.

The following bullets summarise the main different grades of aluminium scraps, with indications on main source, recyclability and market price: Clean HE9, best quality scrap, typically from doors and windows; Painted HE9, same as the previous one but painted, is characterised by lower cost; Poly Cuts, bonded with a polyethylene coating on one or both sides, hard to recycle, therefore characterised by a very low cost; Clean Alloy Wheels, widely available after vehicles scrapping, where it is largely used due to strength and durability; it is easy to recycle; Commercial Pure, 99% aluminum metal content, one of the strongest forms of aluminum for building materials; very good quality and recycling ease; Ali Cable, used instead of copper for larger cables than domestic ones like overhead power cables; widely accepted for recycling; Cast and rolled aluminum, high-quality products manufactured in this way are widely accepted for recycling when they become scraps; Iron Aluminum, typically contaminated with other elements including iron, but also wood and plastics, are accepted if aluminum content is at least 70 % and iron content less than 30 %.

As concerns the potential use of higher amounts of painted scrap in the production process, this is considering feasible, provided that a pre-processing is carried out. This pre-processing step should foresee the adoption of a suitable separation method like manual or automated optical sorting, followed by a dedicated cleaning phase; thermal de-coating is a suitable technique, since it has a high efficiency and allows abatement of pollutant emissions and reuse of thermal energy from paint particles combustion.

As example, a plant for aluminium production located in Turkey has many companies collecting metal scraps, among which the main players are Zafer Geri Dönüşüm, Çolakoğlu Metalurji, Bimel Metal, AK GERİ Dönüşüm, Yeşiltaylar, Jet Metal Turizm, Öncü Metal Hurdacılık, , Alfa Geri Dönüşüm, Tamay Metal, Sariyerli Kardeşler, Erdemir, Ferromet Mümessillik Ve Tic. A.Ş.

In the case the aim of the plant studied is to use its internal painted aluminium scraps within RETROFEED project; indeed, there are approximately 170-200 t/month of scraps produced in different business centers; if the technological solution is validated successfully, the plant could also supply painted scraps from two potential suppliers, named Alimex and Son Adım.

The average aluminium scrap price is linked to the price of aluminium on the London Metal Exchange; as of November 2020, the average price for aluminium scraps is of 1,600-1,700 €/t, with lower values for painted scraps, around 1,500 €/t. If it is compared with the values of primer aluminium, the use of painted scrap can saved around 300-350 €/t (without considered the pre-treatment cost of the painted scrap).

4.4 Steel sector

4.4.1 Biochar as alternative feedstock

One of the most used carbonaceous materials by industry is anthracite. One drawback is that it is produced from fossil fuels, for this reason a research study was done considering biochar as heating agent to substitute anthracite. Biochar, derived from the carbonization of biomass, is a kind of solid fuel with several advantages. Utilization of biomass in ironmaking process has the aim to contribute to energy conservation, emission reduction, and can partially replace the use of anthracite.

As the biomass types are varied and the production processes of biochar are diverse, the quality and properties of commercial biochar could differ from each other greatly.

A comparison of costs of the petcoke against the biochar (coming from the 5 different suppliers contacted) has been performed considering different prices of the CO_2 allowances. These values have been introduced together with the purchasing price of the petcoke (three different scenarios have been studied with a purchasing average prices of 112,5 €/t of petcoke). The price of the emissions of CO_2 (from 14 to 44 €/tCO_2) for the petcoke (emission factor of 2.971 tCO_2/t) and the biochar (emission factor of 0 tCO_2/t since it is considered carbon neutral). The evolution of petcoke price with CO_2 allowance cost shows, in the current situation with a purchasing price of 24-30 €/tCO_2, the prices of biochar are very far away of the price of the petcoke, even considering the price of the emission of CO_2. Unfortunately, even considering that the price of emissions could increase considerable in the following years to values higher than 40 €/t CO_2, if the purchasing price of the petcoke and the biochar do not suffer variation, the use of biochar in the steel sector it is not economically feasible.

In this work, it was studied also the option of the economic feasibility of converting biomass into biochar by an intermediate center and using this product as energy source in the steel production line. An analysis conducted on a biochar production of a torrefaction process was proposed in the study after reviewing the state-of-the-art technologies to produce biochar. The torrefaction process produces the solid product called torrefied biomass, which is the main product and has better fuel characteristics than the original biomass. During the torrefaction process a combustible gas is released, which is utilised to provide heat to the process.

Three economical scenarios were analysed from torrefaction plants (according different technologies) in which the price of the energy per kilogram of biochar produced (MWh/kg) was calculated from forestry wood as biomass. In all cases, current prices and lower and upper price values of biomass were considered. The case 1 was considered a plant with a fossil petcoke annual utilisation in the process as 8,000 ton/y and the torrefied char process demand of 19,200 ton/y of biomass for the production of 12,800 t/y of biochar. In the case 2 was considered a torrefaction plant from the supplier with a capacity of 17,520 Ton/y which includes grinding, pre-drying, conditioning, torrefaction, cyclone reactor, boiler unit and pelletizer. The case 3 was carried out to a torrefaction plant from literature [13]. A similar analysis from the case 1 and 2 was performed.

For the case 1, the biochar prices are close to the petcoke prices; it means that the use of biochar in the steel sector could be economically feasible. In this case it is almost equivalent to produce biochar than to continue using petcoke since CO2 emissions will be reduced compared to petcoke; however not for case 2 or 3. In the case that the price of CO2 emissions could increase in the following months to values equal or higher than 40-45 €/t CO2 and if the purchasing prices of the petcoke and the biochar do not suffer variation, the use of biochar might be feasible for the case 2. In this scenario, the price of emissions might be the same for both the petcoke and the biochar produced. There are no trends for case 3, neither for the medium or long term.

It is important to mention that the variation of production costs and the type of technology are the main reasons which lead to a wide range of biochar prices.

4.4.2 Plastic grains

The steel production process at the plant studied employs natural gas and anthracite among main inputs, and the identified opportunity for enhanced exploitation of circular feedstocks is related to the use of plastic grains as input material.

Plastic grains can be manufactured from a wide range of plastic waste materials (PP, HDPE, PPCP, LLDPE, LDPE, etc.), but the production process is almost the same, with differences related only to the amount and type of additives needed. The possibility to create the desired mix of input materials and additives allows obtaining a plastic grain of the desired composition for recycling into new products (through injection molding and extrusion) or reuse in other production processes.

The largest producers of plastic grains in the world according to the “Global Plastic Granules Market 2020” report [14], the are the following companies: Dar Al Khaleej Plastics, Nahata Plastics, Vanshika Plastic Industry, Balaji Plastic, Navkar Industries, Shakti Plastic Industries, Tejes Plastics, Wiwat Plastic.

The market price from these producers is between 650 and 1,300 €/t for colored plastic grains and between 800 and 1,000 €/t for natural plastic grains. On the other hand, waste plastic grains have a much lower price, below 200 €/t in the EU market, which makes their use competitive with that of other conventional fuels.

4.4.3 Rubber

Concerning rubber, the two most important sources of waste materials are tires and inner tubes; due to the vulcanising process that they undergo, it is difficult to recycle these materials through standard methods for thermoplastics. Therefore, one of the main processing activities carried out for waste rubber foresees their grinding and subsequent use in processes like asphalt production.

4.4.4 Internal wastes

The waste materials studied are dust and sludge.

Dust, which is separated from process gases through dedicated filters (fabric filters, electrostatic precipitators or scrubbers), includes that formed in the re-pouring of molten iron or steel and also in exposure of hot metal to air, as well as in oxidation and evaporation steps. Dust collection is very efficient thanks to the advanced filters and techniques available for flue gas treatment; this means that a large amount of dust is collected, which constitutes a benefit for the environment where this material is not emitted anymore: however, potential uses shall be identified in order to avoid disposal. Depending on the type of flue gas treatment adopted, dust can be separated in dry or wet state; the second is mainly adopted when explosion risks exist and produce a sludge that can be reused only after drying.

Sludges typically contain high levels of CaO, Zn, Pb depending on the type and chemistry of scrap used during steelmaking process; their high moisture content (35–40 %) is a major obstacle to recycling to the sinter plant, since it becomes sticky and forms agglomerates. Therefore, sludges need to be optimally dried and made manageable before recycling. Pilot projects have also focused on the pelletisation of dried sludges with the aim to increase their recyclability.

Dust and sludges contain high amounts of iron oxides and carbon and are therefore interesting for internal recovery or sale to other industries like cement production plants and electric motors cores production. Dusts have also been used as replacement of clays in the traditional brick manufacturing process, achieving energy savings, environmental and economic benefits.

4.5. Agrochemical sector

The dependence on mineral mines as sources of raw material in fertilizers, together with the high production costs and the search for a circular economy, have focused the search for alternative raw materials. These alternative sources would be more sustainable, with an adequate potassium and phosphorus content, allowing to minimize the use of phosphoric acid in the production of NPK fertilizers.

4.5.1 Ashes from biomass combustion

Ashes are one of the by-products generated during the burning of biomass. Currently, the ashes are in the focus of study due to their possible treatment and recycling for different uses, among which are fertilizers. In the market there are different types of ashes depending on the raw material of origin.

Ashes from biomass include vegetable residues of agricultural and forestry origin, vegetable residues from food processing, fibrous vegetable residues from paper production, cork and wood residues (except those that may contain heavy metals).

When comparing the different bibliographical references, it can be seen how the potassium and phosphorus content in the various groups of ash sources have different values for the same typology. This is due to the fact that the ashes are not homogeneous. Also, the conditions of the combustion process can generate deviations between experiments.

Despite this, it can be observed that in the woody biomass group, ashes from olive wood are an exceptional source of potassium and phosphorus, while ashes from pine would show potential only in potassium. In the case of herbaceous biomass, it has been observed that the straw (depending on the origin: barley, corn, triticale, etc.) shows a high content of potassium and phosphorus.

On the other hand, in the ashes coming from agro-industrial biomass, olive pomace, olive cake, almond and sunflower shells, and rapeseed pods as a source of potassium are outstanding, while the ashes coming from olive pits show a high content of both potassium and phosphorus.

However, it should be noted that even though the nutrient composition of the ashes from each type of waste or starting biomass is known, power plants usually use a mixture of different types of biomass as an energy source. In this way, the mixture of different types of biomass generates a final ash composition that is difficult to evaluate and estimate. Also, it is important to mention that the composition and physical-chemical characteristics of these materials are variable due to factors such as the type of biomass, temperatures, combustion conditions or efficiency in particle separation, as has been previously commented.

4.5.2 Ashes from meat and bone meals

Another alternative source from which nutrients can be extracted to generate fertilizers and at the same time help to valorize waste is the ashes of meat and bone meals (MBM). MBM is waste from slaughterhouse by-products, whose use in agriculture as organic fertilizer is regulated by Regulation (EC) No 1774/2002 of the European Parliament and Council. These are products rich in organic matter, nutrients such as nitrogen and phosphorus, as well as amino acids. The amount of these wastes has increased to more than 18 million tons per year in the European Union [15].

From the BSE (Bovine Spongiform Encephalopathy) disease that took place at the end of the 20th century and beginning of the 21st century, and the toxins that it may contain, a classification has been made and some regulations have been established for meat waste, known as by-products of animal origin, not destined to human consumption. The regulations that determine the use of this waste have been varying and changing according to European legislation.

MBM could be an alternative source of phosphorus both in themselves and in their ashes. The phosphorus content is higher in the ashes sample than in the meat meal or meat and bone meal samples, 14 wt. %, 3.4 wt. % and 5.3 wt.% respectively.

4.5.3 Struvite

Struvite is the name given to magnesium ammonium phosphate hexahydrate. It is a white crystalline substance whose components are magnesium, ammonium and phosphorus (MgNH4PO4-6H2O) and is found naturally in geochemical and biological systems [16] [17].

In recent years, struvite has generated interest as a route for the phosphorus recovery because its rich composition in nitrogen, phosphorus and magnesium makes it a potential product in the fertiliser industry. It is a compound that is obtained from various sources of organic waste recycling, industrial and urban wastewater treatment, and agricultural waste. The phosphorus that is associated with the organic matter is extracted through the precipitation and crystallisation of struvite in anaerobic conditions by the bacterial action. It is found in manure, sludge from sewage treatment plants, organic fraction of domestic waste, effluents from food industries, slaughterhouses, etc.

The average phosphorus content is high, depending on the origin of the source to be recovered. For example, manure 572 PO_4^- (total P, mg/L), municipal wastewater 21-273 PO_4^- (total P, mg/L) or pig farm 39 PO_4^- (total P, g/kg). However, the potassium content is very low and negligible.

Currently, obtaining struvite from industrial, agricultural and municipal waste is being studied. Struvite precipitation is a new alternative for obtaining it. Now technologies are needed to be able to extract it. Due to its recent interest, technologies are developed on a small scale or as pilot plants, and in development to achieve higher efficiency and a higher extraction of phosphorus. The availability of struvite for being used as an alternative source of phosphorus is currently small and inadequate because its technology and the process of extraction is still under development and has not been implemented on a large scale. Despite this, the research and studies carried out show great potential and market focus on this resource in a not too distant future.

5 CONCLUSIONS

Based on the information compiled, several conclusions can be drawn pertaining to the incorporation of alternative feedstock in each industrial sector.

- In the ceramic sector, regarding the raw materials, just with the lithium feldspar there is a risk in terms of supply due to the use in batteries. In this moment, the industry in this sector use as alternative feedstock recycle of glass culets and fly ashes, however their use is limited due to impurities and some oxide content. Therefore, the best way to contribute to the circular economy and raw materials savings in this industry it is by the optimization of the process in order to reduce the amount of the waste frits generated, and valorize inside the plant this residual product.
- Regarding the cement sector, biomass, RDF and tires are profitable as alternative feedstock for the decarbonization of the sector, which may be accelerated if biomass is employed instead of the other fuels, since its emissions factor it is very near to 0. Regarding RDF, it is important to standardize and manufacture this product to decrease the moisture content and therefore make it suitable for clinker production.
- In the aluminum sector, the use of painted scrap could be feasible in economic terms and will give a second life to these residues. The pre-treatment process required for integration in the production scheme is being developed as part of the RETROFEED project.
- The steel sector, revealed that the high prices of alternative feedstock such as plastic grains and biochar, make the purchase of fossil fuels still economically preferable. An increase in the price of CO_2 emissions in the future or the reduction of the production costs of biochar are factors that would guarantee the substitution of fossil fuel carbon in the medium and long term. Currently, the steel sector must continue its route towards a circular economy, considering the option to reuse its internal waste products in a suitable manner, and prospective the way of optimizing the use of alternative feedstock in its process.
- In the agrochemical sector, the use of alternative feedstock as a new source for the production of NPK fertilizers could be achieved, since there are resources of ashes of biomass in the surrounding area of the industry studied with an acceptable composition, even thought experimental trials should be done in order to assess if the use of the new alternative feedstock with the new components can produce a negative reaction in the plant and in the quality of the final product.

Overall, there is great potential for the use of alternative feedstock and industrial wastes to catalyze the transition towards more sustainable production practices, achieving either industrial decarbonization and partial supply autonomy. The profitability of incorporating these feedstocks, however, should be analyzed thoroughly for each specific industry, since the proximity of these resources and their inherent qualities, should not hinder quality of the final products or make companies incur in exorbitant expenses due to the creation of complicated logistics chains or pre-treatment steps. It is expected that through the activities carried out as part of RETROFEED in the future months, pathways to overcome these issues are demonstrated and most adequate solutions provided so that the actions can be replicated across all different resource and energy intensive sectors.

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7 ACKNOWLEDGEMENTS

This publication is part of a project that has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 869939.

The work was performed in the framework of the European project RETROFEED (Grant Agreement No 869939) "Implementation of smart retrofitting framework in the process industry towards its operation with variable, biobased and circular feedstock".

This contribution is made possible by the AGROinLOG project "Demonstration of innovative integrated biomass logistic centres for the Agro-industry sector in Europe"