Sustainable waste management in Croatia: Using Life Cycle Assessment to achieve a circular economy

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Transition to a climate-neutral, resilient and environmentally sustainable economy provides both opportunities and challenges. The main umbrella development document in Croatia is National development strategy of the Republic of Croatia until 2030. Integrated national energy and climate plan for the Republic of Croatia for the period 2021-2030 and Low carbon development strategy of the Republic of Croatia until 2030 with a view to 2050 are paving the way for the transition to a sustainable competitive economy, in which economic growth is achieved with low greenhouse gas (GHG) emissions. The new growth strategy of the European Union formulated through the European Green Deal aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy.

Sustainable waste management and resource efficiency are important pillars in developing a global low-carbon economy. Development of low-carbon scenarios includes existing legal framework of Croatia and adopted EU legal framework in waste sector, with the achievement of prescribed waste management objectives to encourage the transition to a circular economy (CE) in which the value of products, materials and resources is maintained for as long as possible and waste generation is reduced to a minimum. Development of climate neutrality scenarios includes the goals from a New Circular Economy Action Plan for a Cleaner and More Competitive Europe, adopted in 2020. The concept of circularity sets out intensive implementation of measures in the period up to 2035 as well as raising the level of resource efficiency, recycling, reuse and waste management targets by 2050.

"Closing the loop" and returning resources back into the material cycle create a win-win approach that benefits both, the economy and the environment. The CIRCE2020 project (Expansion of the CIRcular Economy concept in the Central Europe local productive district) refers to the adoption of an integrated approach to environmental management in five industrial areas of Central Europe (Italy, Poland, Austria, Hungary, Croatia) by changing patterns from single company recycling interventions to an integrated redesign of industrial interactions based on the CE concept. The goal is to introduce innovative cross-value chain waste governance models and transnational analytic tools to improve capacities of concerned waste public-private sector to reduce dependencies from primary natural resources within industrial processing. The aim of CIRCE2020 is the realization of a set of pilot actions based on the results of local surveys to identify the unevaluated waste streams using innovative instruments derived from the Material Flow Analysis (MFA), Life Cycle Costing (LCC) and Life Cycle Analysis (LCA).

For the project, analyses of the industrial waste in Split - Dalmatia County (SDC) in Croatia was conducted. MFA analysis was conducted to identify waste streams (waste from fish processing industry and olive fruit processing) for further consideration and LCA/LCC analysis. Regarding MFA analyses, waste from the fish by-product is decided for further analysis. The LCA/LCC analysis was made for biological waste from fish processing with focus on valorising biological by-product after cleaning/gutting of fish.

The project envisaged simple and inexpensive methods to extract fish oil from fish by-products and thus bridge the gap between the waste producer (by-product) and the food additive manufacturing industry. In the process of fish oil extraction, protein fish meal is produced and is intended to be used as animal feed. To the complete valorisation of the fish by-product, the method affects the cost of transport, since the extraction of fish oil reduces the need to transport the by-product for disposal. The extraction process produces water, protein flour and fish oil. The processing industry can experience significant positive financial effects by placing on the market project-based products (fish oil, protein fish meal) and avoiding the cost of waste disposal.

Conceptual CE solution envisions exploitation of fish by-products for obtaining most valuable substance of fish by-product contains omega-3 fatty acids, high-value raw materials for the pharmaceutical and food markets. Goals of the study is primarily aimed to quantify and compare LCC of Business as usual (BaU) and CE scenarios of fish by-product management from the fish processing industry and identify LCC hotspots of the envisaged CE technology solution that may be used for a further improvement of the CE technology solution. BaU and CE solutions produces different products from the same raw material (fish tissue by-product). CE solution envisions exploitation of by-products with the aim of obtaining high-value raw materials for the pharmaceutical and food

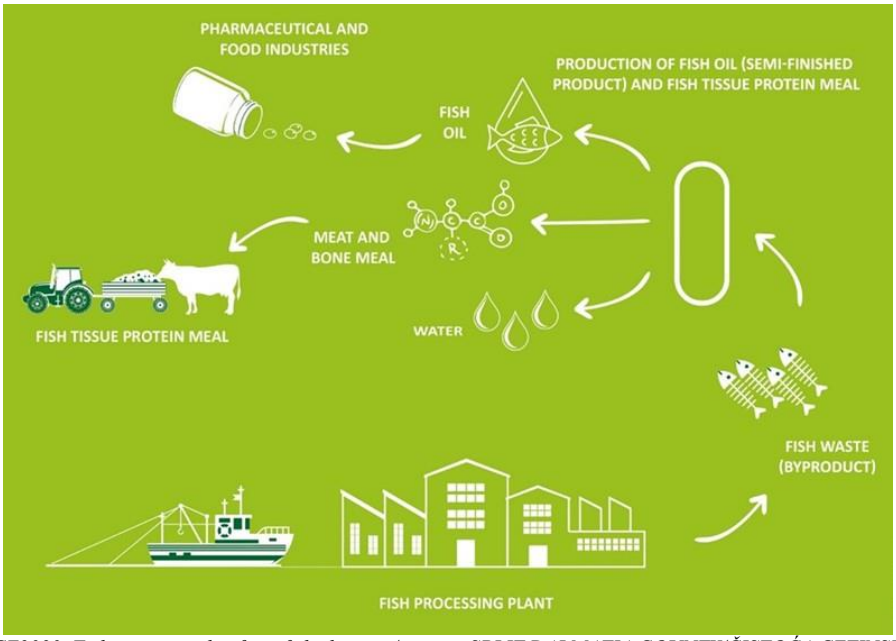
markets. BaU scenario utilizes fish by-products to produce a low value product, animal feed and energy recovery. This study is a comparative LCC analysis, with the aim of comparing the difference between CE and BaU scenarios that are quantified and reduced to the level of a one functional unit. The focus is on evaluating potential improvements in processes and systems and identifying cost hotspots and potential for further improvements to the conceptual CE solution.

Environmental hotspots of BaU and CE scenarios show climate change and depletion of abiotic resources (Resource use - fossils) as dominant impact categories, accounting for more than 70% of the environmental burdens of both scenarios.

CE scenario enables much greater financial opportunities to exploit fish by-products, but with considerably higher initial investment. BaU solution does not valorise fish by-product in the optimal way. Complete valorisation of fish by-products and production of high-value pharmaceutical and food products (CE scenario) results with almost 3 times higher net present value than the BaU scenario, but this comes at a high cost of investment, which in the observed period of 15 operating years means a significantly lower profitability index than the BaU scenario. About 92% of investment costs falls to the supercritical fluid fractionation (SFF) and transesterification process of omega-3 fatty acids. Considering that a simple and cheap wet reduction process separates fish oil from fish by-products and that transesterification and SFF processes are used for fish oil refining, optimal application of CE solution should consider the possibility of valorisation fish by-products in a way that locally, at the place of production of fish by-products, only wet reduction process is carried out which will produce unrefined fish oil (semi-finished product), protein (finished product) and water. Water would be properly disposed of; fish protein could immediately be sold to the animal food market and the unrefined fish oil could be transported to further processing in some of the existing pharmaceutical or food plants (Figure 1).

It is proposed construction of (1) centralized biorefinery for collection fish by-products and process them in a centralized facility; (2) centralized plant for the processing of fish by-products (wet reduction process) and production of protein (finished product) and fish oil (semi-finished product) with the analysis of possible marketable placement of extracted fish oil and (3) wet reduction unit alongside fish processing plant (waste donor) for fish oil and protein extraction with an analysis of fish oil (semi-finished product) market placement.

Figure 1. “Closing the loop” - fish oil and protein extraction from fish by-products.



Source: CIRCE2020, Fish tissue residue from fish cleaning/gutting, SPLIT DALMATIA COUNTY/ČISTOĆA CETINSKE KRAJINE, https://circe2020.eu/Solutions/Details/19

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