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Abstract	The aim of this deliverable is to outline the benefits of using socio-economic approaches to assess the performance of seafood circular economy. This technical report details several socio-economic tools and their principles.

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SUMMARY

Within the European agenda for sustainable growth, the European Commission has adopted a new Circular Economy Action Plan aiming at not only ensuring material savings but also generating extra added value and unlocking economic opportunities. Within the European Atlantic area, commercial alliances and common interests in food production and consumption are numerous, particularly for seafood. To measure the benefits and disadvantages of potential changes along the value chain, stakeholders need to be provided with tools to guarantee positive environmental and economic balance. This technical report illustrates how circular economy could be applied to fisheries, aquaculture or seafood production sectors. It also details several tools that could be deployed for the assessment of socio-economic performance and in particular the tool developed by Vertigo Lab, the ImpacTer model that will be processed on different case studies. The use of economic assessment tools can help bring valuable arguments to design transformative economic systems and increase the ability for decision-makers to mainstream circular economy into business models.

1. INTRODUCTION

Fisheries and aquaculture are important contributors to EU food and nutritional security (The World Bank, 2013). Two thirds of EU seafood are imported and 60% of the wild fish consumed is caught beyond EU waters (Bell et al., 2018). Moreover, these sectors still face challenges such as the fish stock exploitation sustainability, the discarding of unwanted fish (European Environment Agency, 2014), competition for space, markets and administrative constraints for aquaculture (Bell et al., 2018). The development of circular economy is seen as an opportunity to rethink growth models that tackle scarcity and resources' vulnerability while providing employment and industrial opportunities.

Within the European new agenda for sustainable growth – the Green Deal - the European Commission has adopted a new Circular Economy Action Plan in March 2020 (COM(2020) 98 final). The plan aims not only at ensuring substantial material savings throughout value chains[1] and production processes but also at generating extra value and unlocking economic opportunities. Within the European Atlantic area, commercial alliances and common interests in the production and consumption of food are numerous, particularly in the case of seafood. The concept of food-water-energy nexus has lately attracted attention across academic research and policy sectors. This nexus aims at highlighting the linkages between water, energy, food production systems and natural ecosystems to foster a win-win-win strategy for human well-being and environmental sustainability (Ringler et al., 2013). Working on a holistic approach balancing the nutritional, economic, and energetic value of the seafood sector may provide opportunities to address barriers and strengthen these sectors regionally and across jurisdictions in the Atlantic region (Ruiz-Salmon et al., 2020).

2. CIRCULAR ECONOMY AND SEAFOOD SECTOR

1.1 The definition of circular economy

There is neither a commonly accepted definition of Circular Economy (CE) nor a clear typology that would allow classifying CE practices (Kalmykova et al., 2018). Rizos et al. (2017) summarize some of the definitions among which we retain the French Environment and Energy Management Agency's one as it links the environmental stakes with the well-being ones: "CE can be defined as an economic system of exchange and production that, at every step of the product life cycle stages (goods and services) aim at increasing the effectiveness of resources' use and at reducing impact on the environment while developing human being well-being" (ADEME, 2014).

[1] According to the Porter's Value Chain, the value chain can be defined as the **Primary Activities** that relate directly to the physical creation, sale, maintenance and support of a product or service (inbound logistics or supply, operations or processing, outbound logistics or distribution, marketing and sales, service or after-sales services) and **Support Activities** (procurement or purchasing, human resource management, technological development, infrastructure).

To assess the benefits and disadvantages of potential changes in the technology regimes along the life cycle of products and processes, product developers need to be provided with tools that enable them to compare different circular strategies and ensure positive environmental and economic balance of new CE practice. Therefore, assessment across the multiple dimensions of the value chain multiple dimensions (extraction, production, processing, trading, transport, storage) is needed to identify economic costs and value addition. Figure 1 presents the different typology of processes within CE value chain and its consequences on the environment and illustrates the need for stakeholders' behavioural changes.

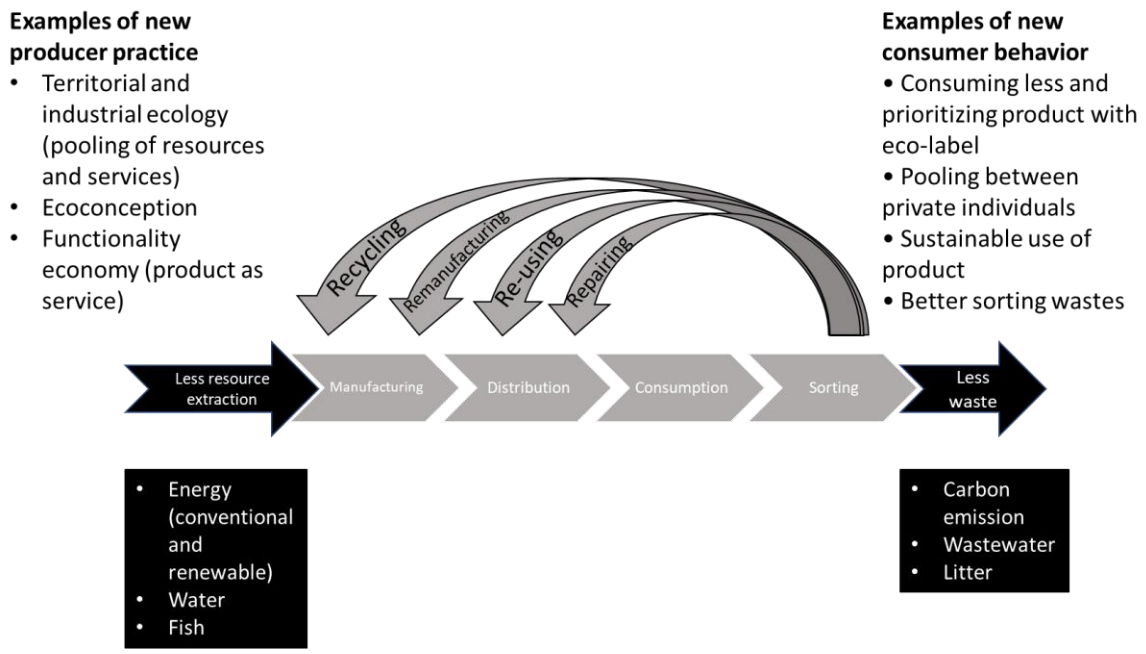

Figure 1 : Circular Economy practices along the value chain (grey boxes) with environmental impacts (black boxes) (adapted from ADEME, 2014; Rizos et al., 2017 and Burch et al., 2019)

1.2 The application of circular economy to the seafood sectors

The application of the different CE approaches to seafood production systems is presented below identifying for each environmental pressure the relevant EC practice and the associated socio-economic benefits (Table 1 for fisheries and Table 2 for aquaculture).

Table 1 : EC practice applied to fisheries' sector

Source of pressure on the environment		*Potential solutions to reduce environmental pressure*	*Examples of EC measures*	*Examples of socio-economic benefits related to the integration of EC practices*	*Sources*
Greenhouse gas emissions	*Fuel consumption*	*More efficient engine*	*Eco-design: Reducing energy consumption and carbon emissions*	*Operating costs less sensitive to changes in diesel prices*	*Planchot and Daures, 2008; Gulbrandsen, 2015*
Physical pressure on the benthic environment	*Seabed integrity and habitat loss*	*Improvement of fishing gears and selection of fishing zones*	*Eco-design: Reducing energy consumption and carbon emissions*	*Indirect benefits:* *Resource preservation* *Reduction of fuel consumption using new fishing gear*	*Gulbrandsen, 2015;* *Rijnsdorp, 2017*
Biological pressures	*Ecological status of exploited species*	*Sustainable and ecosystem-based management of fisheries*	*Non addressed in CE*		
	Impact on unwanted species *Biological diversity and species abundance* *Food web*	*Processing and valorisation of by-products* *Zero discard*	*Turn production « waste » into a resource*	*Valuation of non-valued resources and income diversification* *Preserve resources* *Creation of waste recovery channels*	*Batista, 2007; Le Floc'h, Bourseau, Daurès et al., 2011; Burch et al., 2019*

				Provide new business opportunities for forward-thinking entrepreneurs	
Marine debris	*Fishing nets, strapping bands, gloves, polystyrene fish crates, buoys etc.*	*Eco-designed materials* *Recycling*	*Turn production « waste » into a resource* *Making usage more circular: reusing*	*Creation of waste recovery channels* *Provide new business opportunities for forward-thinking entrepreneurs* *Increasing the resilience of local communities by strengthening networks and collaboration*	*Burch et al., 2019; Du Payrat et al., 2020*

Table 2 : EC practice applied to aquaculture's sector

Source of pressure on the environment		*Potential solutions to reduce environmental pressure*	*Examples of EC measures*	*Examples of socio-economic benefits related to the integration of EC practices*	*Sources*
Greenhouse gas emissions	*Fuel consumption*	*More efficient engine*	*Eco-design: Reducing energy consumption and carbon emissions*	*Operating costs less sensitive to changes in diesel prices*	

Physical pressure on the benthic environment	*Accumulation of detritus and sediments*	*Recirculating circuit systems (aquaponie) – integrated multi-trophic aquaculture*	*Reducing resource consumption* *Turning waste into a resource*	*Pooling of water flows - diversification of productions*	*Eyrolles et al., 2019;* *Tocqueville et al., 2019*
Biological pressures	*Eutrophication*	*Methanogenic and fertilizing potential of aquaculture waste*	*Turning production « waste » into resources*	*Energy input to the production farm – lower production costs – farms energy self-sufficiency*	*Ndiaye et al., 2020*
Waste production	*Shellfish waste production*	*Use of shellfish for agriculture or cement production*	*Turning production « waste » into resources*	*Valuation of non-valued resources – income diversification* *Creation of waste recovery channels* *Provide new business opportunities for forward-thinking entrepreneurs*	*Du Payrat et al., 2020*
Marine debris	*Fishing nets, strapping bands, gloves, polystyrene fish crates, buoys etc.*	*Eco-designed materials* *Recycling*	*Turn production « waste » into a resource* *Making usage more circular: reusing*	*Creation of waste recovery channels* *Provide new business opportunities for forward-thinking entrepreneurs* *Increasing the resilience of local communities by strengthening networks and collaboration*	*Burch et al., 2019;* *Du Payrat et al., 2020*

About processing and distribution circuits, seafood production has similar impacts than other agro-food industries. The latter has important environmental impacts being the third most energy-intensive sector (Bas-Defossez et al., 2018). These industries are strong water users (e.g. in France, agri-food industrial discharges represent 20 % of the wastewater of French industry according to Mathieu-André, 2000) and packaging specifically produces large amounts of waste. Among existing CE approaches, seafood industries can improve products valorization (avoiding waste) and co-products. Fish processing is particularly concerned since marine co-products and by-products represent on average 50% of the weight of total raw material used (Delannoy and Coquelle, 2017). The reflection on packaging is also included in the CE with a waste minimization approach. Moreover, fish and fish products are among the most widely traded food products in the world (FAO, 2018). In 2016, about 35 % of the World's fisheries production was traded internationally through various products for human consumption or non-food uses. The food goods transport sector represents a major source of greenhouse gas emissions. But transportation impacts of agri-food and seafood products cannot be compared as exportations of agri-food products are much higher (in 2018, French seafood exportations represented only 3% of agri-food exportations, Insee Références, 2020). Bringing places of production closer to places of consumption is therefore a challenge for the entire food sector, including seafood.

2. SOCIO-ECONOMIC TOOLS FOR ASSESSING CIRCULAR ECONOMY PERFORMANCE

2.1 Correspondence between environmental and socio-economic performance tools

Based on the work from Le Gouvello et al. (2019), the different tools currently available to carry out a socio-economic analysis in CE are synthetized in

Table *3*. This typology enables to highlight the synergies between approaches aiming at assessing environmental performance and approaches aiming at evaluating economic performance.

Table 3 : Main tools used in CE. Adapted from Le Gouvello (2019), Elia et al. (2017), Loiseau (2014), Iacovidou et al. (2017) and Bruel et al. (2018)

Methodological tools	Principle	Scale	Corresponding socio-economic analysis
Material Flow Analysis – Material Energy Flow Analysis	Analysis of material physical flux, energy and substance	Micro, meso, macro	Material Flow Cost Accounting

– Substance Flow Analysis			Resources' productivity (GDP/material)
Life Cycle Assessment	Compilation and assessment of inputs and outputs and environmental impacts for a product or a process during its life cycle	Micro, meso	Territorial LCA Social LCA Life Cycle Costing – LCC Full Cost Accounting – FCA
Energy, Emergy, EXergy analysis	Environmental Accounting based on emergy and exergy	Micro, meso, macro	
Ecological footprint (water, carbon material)	Pressure measurement exercised by human being on biosphere to respond to his resources and water consumption, and its waste absorption needs	Micro, meso, macro	
Physical Input-Output analysis	Material physical flux Input-Output balance	Meso Macro	Macro-economic Input – Output Tables
Monetization of costs and benefits	Expected monetary or monetized costs and benefits' identification across economic, social, and environmental domains over a specified time	Micro, meso	Cost-Benefit analysis

These economic tools can provide useful insights for the analysis of value chains' analysis with a nexus approach. Nevertheless, the choice of the relevant method will depend on the scale of the analysis related to the problem framing and the available data and the choice of value metrics. Here, we detail their principles with examples stemming from fisheries, aquaculture, and seafood production.

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2.2 Economic tools and their related principles

Material Flow Cost Accounting – MCFA

MFCA combines monetary and physical data quantifying energy, material consumption, and waste output in physical and monetary units by applying the cost absorption method[2] throughout the following steps: transformation, storage, transport, consumption (Walz & Günther, 2020). It constitutes a relevant tool to improve economic and environmental performance of industries at a single enterprise scale (e.g., Nguyen, 2018 analyzes a small seafood processing industry in Vietnam) or at a regional scale (e.g., Le Gouvello, 2019 provides evidence of hidden costs of fish discards along coastal fisheries' value chain).

Life Cycle Costing – LCC

LCC evaluates all costs associated with the life cycle of a product that are directly covered by the actors in that life cycle (e.g., supplier, producer, user or consumer) including those involved at the end of life. LCC may also integrate the cost of externalities (e.g., greenhouse gas emissions). LCC is used to identify cost drivers and cost efficiency improvements in the evaluations of different strategies to optimize the cost/quality ratio of a product/service (Petit et al., 2018). Although constrained by the use of a monetary unit, it helps identify trade-offs between environmental, social and economic aspects (e.g., Ruiz-Salmón et al. 2020 detail Life cycle assessment methodologies for fish and seafood processed products or Utne, 2009 examines sustainable fishing vessel investment decisions for ship owners).

Input Output model – IOM

IOM is a linear modelling approach analyzing the relative relationship between the flow of production inputs and resultant flow of produced outputs in an economy. It simulates the direct and indirect impacts associated with changes in levels of output on economic indicators such as national level output, employment, Gross Value Added and the trade balance (Grealis et al., 2017). IOM has been used to analyze the economic and social effects of maritime sectors at national scale (e.g., Grealis et al., 2017 assess the contribution of the Irish aquaculture sector and the economic impacts on other sectors in the economy) or at regional scale (Garza-Gil et al., 2017 measure the effects of fishing and aquaculture on Galician regional economy). Within and IOM approach, the study of some practices within an industry can be challenging (e.g., longline activity by Leung & Pooley, 2001; artisanal fishing fleets by García-de-la-Fuente et al., 2016). IOM can inform the introduction of new measures or regulations (e.g., Cai et al., 2005 for fisheries) or the linkages between different maritime sectors (e.g., Lee and Yoo, 2014 evaluate the role of capture fishery and aquaculture sectors in Korea; Morrissey and O'Donoghue 2013 examine the

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[2] Absorption costing is the process of linking all production costs to the cost unit to calculate a full cost per unit of inventories.

linkages and production effects of the Irish marine sector on the national economy). Nevertheless, IOM only accounts for upstream impacts due to changes in final demand.

Cost benefit analysis – CBA

CBA aims at monetizing costs and benefits and aggregating them onto a single domain and a measurement unit. It also devaluates future costs and benefits through discounting (Iacovidou et al., 2017). CBA is used to assess economic value of an industry (its economic net benefit or rent) and the distribution of the total added value between the different economic agents but not its economic impacts (e.g., Vestergaard et al., 2011 assess the economic contribution of the offshore Greenlandic shrimp fishery to the economic welfare of Greenland). It is currently difficult to apply a value chain approach to the CBA valuation context (Petit et al., 2018).

The economic potential of CE approaches in fisheries, aquaculture or seafood production sectors has not yet been investigated through these different tools. Their use can provide useful arguments (reduction of hidden costs, improved added value, increase in employment rate, etc.) to the value chain stakeholders to implement more sustainable practice.

3. THE USE OF AN INPUT-OUPUT MODEL DEVELOPED FOR TERRITORIAL DIAGNOSIS AND IMPACTS STUDIES FOR POLICIES AND PROJECTS

In the framework of the WP8, the use of an input-ouput model to assess the performance of CE practice for fisheries, aquaculture or seafood production sectors was favoured as accounting for upstream impacts due to changes in final demand. Vertigo Lab developed an economic model, the ImpacTer model, based on the IOM elaborated by Wassily Leontief (Leontief, 1986). This IOM is employed in the framework of territorial diagnosis and prospective studies assessing projects and policies' impacts at national and regional scales. All intersectoral exchanges are integrated through the commercial interactions between different enterprises and public entities (suppliers / clients / subcontractors exchanges). For instance, the US Bureau of Economic Analysis has developed its own IOM (RIMS II[3]) that estimates regional input-output multipliers for any state, county, or combination of states or counties. The multipliers approximate the impact from changes in final demand on one or more regional industries in terms of output, employment, and labour earnings. Economic impact studies use this model to analyse how projects ripple throughout county, state, or regional economies.

The ImpacTer model was originally developed to be based on IOM published yearly by the French national institute for statistics and economic studies. These tables detail the origin of the products (inland or imported), the destination of these products (how these products are

[3] https://www.bea.gov/news/blog/2019-09-03/bea-updates-regional-economic-impact-tool

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consumed within the territory by the economic agents: the enterprises, the households, and the public administration). Moreover, these tables assess the different inputs (goods and services such as raw materials or support services, employees' remuneration and profits) constituting the value of the business lines' production. They provide a thorough understanding of economic transactions realized between different activities within an economy. The ImpacTer model can equally process data produced by different statistical systems from different countries (e.g the European Statistical System – Eurostat) and thus be used in different contexts.

The IOM allows to analyse the weight of an activity or a project and their impacts on the whole economy distinguishing three types of impacts:

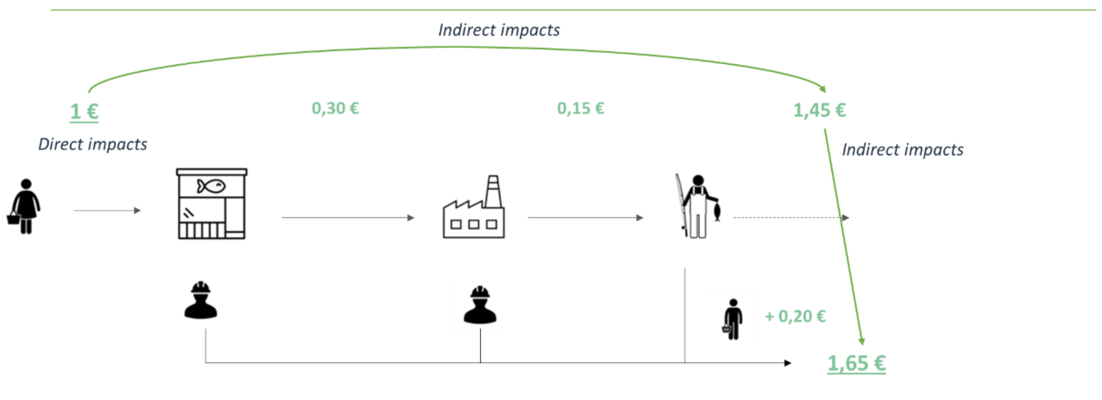
- **Directs impacts**: corresponding to production value, added value and the number of paid employments for a given activity;
- **Indirect impacts**: corresponding to production value, added value and the number of paid employments for the activities providing directly and indirectly goods and services to the given activity;
- **Induced impacts**: corresponding to production value, added value and the number of paid employments that are explained by the consumption of regional products of the salary generated directly or indirectly by a given activity.

The explanation of multipliers with the fishmonger's example:

Assuming a consumer spends 1 euro to buy some transformed fish. 1 € spent by the consumer becomes 1 € of revenue for the fishmonger. With this euro, the fishmonger buys the transformed fish from an industrialist for a value of 30 cents €. This spending of 30 cents € from the fishmonger becomes the revenue of the industrialist. With these 30 cents €, the industrialist buys 15 cents € of fish to the fisherman. These 15 cents € become the revenue of the fisherman.

The production multiplier of indirect impacts for the fishmonger is thus 1+0,30+0,15 = 1,45€.

1 € spent at the fishmonger produces a revenue in the economy of 1,45 €



The choice to use an IOM model such as ImpacTer within Neptunus project has been driven by several reasons. It can be easily applied to different sectors to obtain a state of reference (without the introduction of circular economy) and then compared to prospective scenarios that integrate CE practice. It allows to account for impacts on the upstream of the whole business lines' production. In the framework of a European project, it is crucial to be able to equally process data produced by different statistical systems from different countries (e.g the European Statistical System – Eurostat) through a top-down approach. Local contexts can be then informed through the collection of local data (bottom-up approach).

4. CONCLUSIONS

While most scholarly studies blame the limited progress made in CE on technological barriers (e.g., lacking ability to deliver high quality remanufactured products, limited circular designs, too few large-scale demonstration projects or lack of data), the recent work of Kirchherr et al. (2018) shows that cultural barriers are considered as the main CE limitations by businesses and policy-makers. These cultural barriers are driven by market barriers which are induced by a lack of synergistic governmental interventions to accelerate the transition towards a CE. The lack of studies on socio-economic dimensions of circular economy practices in the seafood sector identified in our brief review can be seen as a hindrance to the implementation of EU Circular Economy Action Plan in this sector. Changing producer and consumer behaviours require to provide value chain stakeholders and governments with adequate tools to help them shift towards sustainable models mainstreaming CE. As mentioned by Petit et al. (2018), all value-chain actors would need to envision their decisions' consequences on their value chain sustainability. Providing them with indicators that allow them to conjointly define their sustainable strategy is crucial. This strongly relies on analysing the economic performance of the seafood value chains with a food-water-energy nexus perspective to address the constrains faced by stakeholders. These insights are crucial to inform new transformative strategies and policies based on circular economy. In this line, within the Interreg Neptunus project, economic implications of seafood circular economy will be assessed on a few case studies in the Atlantic coast through an input-output model (Neptunus, 2020).

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