SEA project:
Sustainable and socially responsible supply chains (4.3)

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Executive summary

- Supply chain scholarship has adopted an expanded view of supply 'networks' to include non-firm actors, who can influence innovation processes and outcomes.
    - The nature of future collaborations between industry players, academia, the local community, regulatory bodies, and local/regional government will play a critical role in the development of competitive and socially responsible seaweed supply chains;
- Research suggests that many promising operational initiatives will fail to proceed to the implementation stage because value chain benefits accruing may not be effectively (or correctly) evaluated from an 'end-to-end' supply chain perspective;
    - one potential mechanism in building and evaluating socially responsible operating models is through the development of sector-specific 'design rules';
- Nascent ideas, with high novelty, will require more 'networked collaborations' to collectively minimise risk and promote resilience; the seaweed sector should aim to involve all citizens in developing new science and innovations and to understand consumer behaviours;
    - From a demand perspective - action research approaches and methods for 'inclusive participation', that can involve local innovation systems in the scaling of any appropriate solutions, are recommended;
    - From a demand perspective - a better understanding of consumer preferences and behaviours to inform product and place choices is also recommended;
- A vision of an innovation ecosystem in the East of England (incorporating supply and demand perspectives) is presented; follow-on funding should support R&D capability building (including the establishment of a local/regioanl seaweed nursery), the development of process technology ('agile' biorefinery equipment), and supporting infrastructure ('digitally enabled' supply chains);
    - A work programme is proposed which could form the basis of the SEA project (Part II).

1. Socially responsible operating (SRO) models

Recent supply chain scholarship has adopted an expanded view of supply networks to include non-firm actors, who can influence innovation processes and outcomes (Kumar et al., 2020; Selviaridis and Spring, 2022). The nature of future collaborations between industry players, academia, the local community, regulatory bodies, and local/regional government will be critical for the development of competitive and socially responsible seaweed supply chains in the region. The exploratory nature of this SEA project aims to inform industrial and governmental policies and strategies, in this regard, to support nascent and emerging seaweed supply chains in a specific regional context. Taking outputs from a range of SEA project deliverables (3.1; 3.2; 5.1), this short report looks to outline potential socially responsible operating (SRO) models.

SRO models could be defined as working with the local community to include 'citizen-led' innovation – from a supply perspective; and to better align outputs (products) with consumer acceptability – from a demand perspective. Central to this is the development of 'needs-based approaches' – participatory/action research approaches and methods to enable 'inclusive participation' (Harrington et al., 2023). For example, a focus on 'inclusion' could enable (i) R&D capability building from a supply perspective through the use of local innovation systems in the scaling of any appropriate solutions; and (ii) from a demand perspective, a better understanding of consumer preferences and behaviours to inform product and place choices (e.g., co-location decisions).

SRO models could also be defined as working in collaboration with disparate stakeholders e.g., the fishing industry and energy companies to co-create additional local employment opportunities and access to prospects in Norfolk and the East of England. From an industry perspective, SRO models should incorporate stakeholder-specific requirements e.g., financial profit (scale required); infrastructure improvement; new revenue stream generation; in-house skills development; building own brand reputation; innovation levels; new service development; and franchising opportunities. From an institutional perspective, SRO models would incorporate other requirements e.g., reputation, economic development; maximising 'customer' satisfaction; technology and innovation transfer; and the promotion of local ('green') business. There will be overlapping interests also, for example, licensing; market growth; network integration; transport times; consumption rates; energy pricing (tax; incentives); and skills development for the region. Norfolk residents may also have very different 'needs', which should be captured. For example, factors such as supporting local businesses, job creation, customer satisfaction (greener products and enhanced choices), and overall service performance (convenience in terms of flexibility and reliability).

Figure 1 summarises these first steps as part of a 'needs-based' analysis (see deliverable 3.1; Harrington et al., 2016). For a supply chain to be both 'competitive' (deliverable 3.2) and 'socially responsible' (this deliverable), issues of social equity, principles of inclusion and measures of fairness must also be taken into account (Harrington et al., 2023). With further development, this framework

can inform what a sustainable and socially responsible supply chain *could* look like, identifying benefits and challenges to the local economy, consumers, inhabitants (society) and the environment.

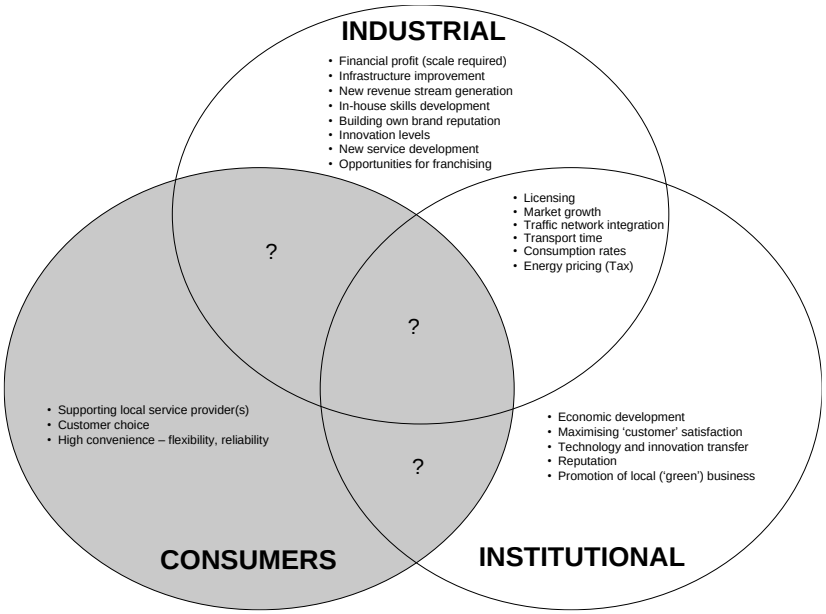

Figure 1. Common interests/trade-offs that may resonate with the seaweed sector in developing socially responsible operating (SRO) models

It has been argued that many promising operational initiatives will fail to proceed to the implementation stage because value chain benefits accruing may not be effectively (or correctly) evaluated from an 'end-to-end' systems perspective (Tsolakis, Harrington and Srai, 2023). As described in deliverable 3.2, one pathway mechanism in building R&D capability through to commercialisation is using the idea of 'design rules'.

Previous case studies suggest that significantly enhanced product variety and/or flexibility should be a focus of emerging supply chains (Srai, Harrington and Tiwari, 2016) and may be a key determinant in industry development. In terms of supply chain design rules – in taking an 'end-to-end' systems perspective - future work should look to develop an 'integrating' decision-making approach to obtain better estimates on end-to-end system performance involving e.g., promising agile biorefinery designs. The progressive digitalisation of production processes in other sectors, distribution channels and product tracking, and the capture and replenishment of customer demand suggest that ICT infrastructural developments that underpin these SRO models may be equally relevant to future evolution. Digital supply network configuration analysis techniques, developed and applied in emerging industry supply networks, such as UK Industrial Biotechnology (Srai, Harrington and Tiwari, 2016; Tsolakis, Harrington and Srai, 2023) could also be utilised to explore decision-making relating to e.g., demand forecasting and inventory management, and where digitally interconnected biorefineries could be located in the UK.

These, together with the observed trend in other exemplar cases (deliverables 3.1 and 3.2) to locate production closer to end-users, suggests seaweed supply chains should be configured based on smaller-scale distributed operations where speed, and product/product-service customised solutions are more attractive value propositions, and where any technology developments can provide viable volume-variety options. Optimised network configurations, as illustrated in deliverable 3.2, can be developed here that can demonstrate the balance needed between the availability of feedstock, the number of manufacturing facilities, and transportation requirements. This design rules approach can provide valuable supporting decision-making evidence in terms of business context/viability, social impact, and value chain opportunity.

This mechanism can also be used to integrate all the knowledge gained from the range of SEA project deliverables over the past 10 months. For example, deliverable 5.1 sets out an existing asset base (expertise and facilities) that can assist in the development of new products and applications using seaweed; where local expertise and partners cancollaborate at the early stages of the product development, and for validation and scale-up stages, external CRO and service providers (with specific certifications) are then used to provide independent validation of products and performance.

Collectively, these provide valuable practical guidance for organisations and individuals on new ‘operating principles’ (i.e., supply chain design rules informing design rules in R&D and processing). Industry and government stakeholders could use these design rules to build a regional plan.

It is anticipated that several iterations of ‘agile and socially responsible’ operations will need to be assessed to evaluate possible changes to the industrial landscape, including changes to feedstock supply, assessment of potential impacts to any existing asset base, and exploring value capture mechanisms for those involved in developing new technologies, applications and products (e.g., from ‘citizen scientists’ to SMEs and larger organisations). Section 2 outlines an “Innovation Ecosystem” in the East of England (from supply and demand perspectives) and a programme of work as potential next steps.

2. An Innovation Ecosystem in the East of England (supply and demand perspectives)

Building R&D capabilities and supporting infrastructure is only part of the challenge of delivering a usable and functional platform for seaweed farming and production in the East of England. The sector could aim to involve citizens in developing: new science and innovations; a deeper understanding of consumer preferences and behaviours to inform product and place choices; and local innovation systems in the transition to sustainable and socially responsible supply chains.

An innovation ecosystem is fundamentally a socio-techno-economic-ecological system, and as part of deliverable 4.3, three connected sets of challenges have been identified which should be addressed (which currently restrict the development of sustainable and socially responsible supply chains).

First, a critical component in ensuring that eventual outputs (products) actually have a market is to co-design implementations with users. Key to this is an 'open science' vision of the ecosystem to promote a shift of science, knowledge and innovation in society towards inclusive, ethical and sustainable outcomes (Smart et al., 2019). Here, the idea of 'open science' can be used to grow the innovation space (by increasing the available process routes) so that 'citizen scientists' can access the innovation ecosystem. There are also opportunities here to develop digital infrastructure for community-based access to, and citizen engagement in, a series of seaweed demonstrators to support any business model development via e.g,. a series of community-based 'Citizen Science' Sandpits.

In promoting how citizens may demonstrate their 'value' to the rest of the Innovation ecosystem, sector maps (developed as part of deliverable 3.1) could be employed to capture individuals, specific innovation communities, and experimentation activities. For example, this could then support the 'micro-innovator' in assessing specific designs. Building on the idea of archetypes and configurations (Harrington and Srai, 2017):

- '*Resource Opportunists*' may choose to engage with, for example, (a) primary feedstock sourcing – linking to firms in the R&D portion of the UK sector map (deliverable 3.1; Figure 2);
- '*Process Enthusiasts*' might explore (b) implications of alternative product-process route combinations for the manufacture of value-added intermediates;
- '*Product Solvers*' might become involved in evaluating (c) end industrial and commercial use applications

However, as mentioned in the previous section, prior research has shown us that many entrepreneurs with promising ideas will fail to progress to a basic feasibility stage because novel benefits accruing may not be effectively (or correctly) evaluated from an 'end-to-end' systems perspective. This is also true of initiatives from larger organisations and SMEs (Tsolakis, Harrington and Srai, 2023). It will be very important to focus on the demand side - on the 'perception' of products derived from seaweed (and potentially seaweed waste streams), by leveraging extensive research in human behaviour and behaviour change (e.g., Ursey et al., 2020).

In sum, three research questions (RQ) central to the development of an innovation ecosystem are:

RQ#1 – What are the barriers for 'micro-innovators' ('Resource Opportunist'; 'Process Enthusiast'; 'Product Solver') when translating novel concepts to 'agile' designs at scale? **(People – Process)**

RQ#2 – What 'operating principles' best match 'agile' biorefinery outputs (products) to the requirements of consumers and emerging demand-side supply chains? **(People – Product)**

RQ#3 – What 'operating principles' best engage all stakeholders, across physical and virtual environments, and provide a foundation for community action on shared goals? **(People – Place)**

To answer these three research questions, a programme of work is proposed to develop an innovation ecosystem.

The Challenge: While innovative ideas and solutions may be novel - with potential for impact in addressing societal needs - they will carry significant risks. Current challenges include suitable test-beds that involve a large enough user-base, and unforeseen ethical and regulatory issues (licences).

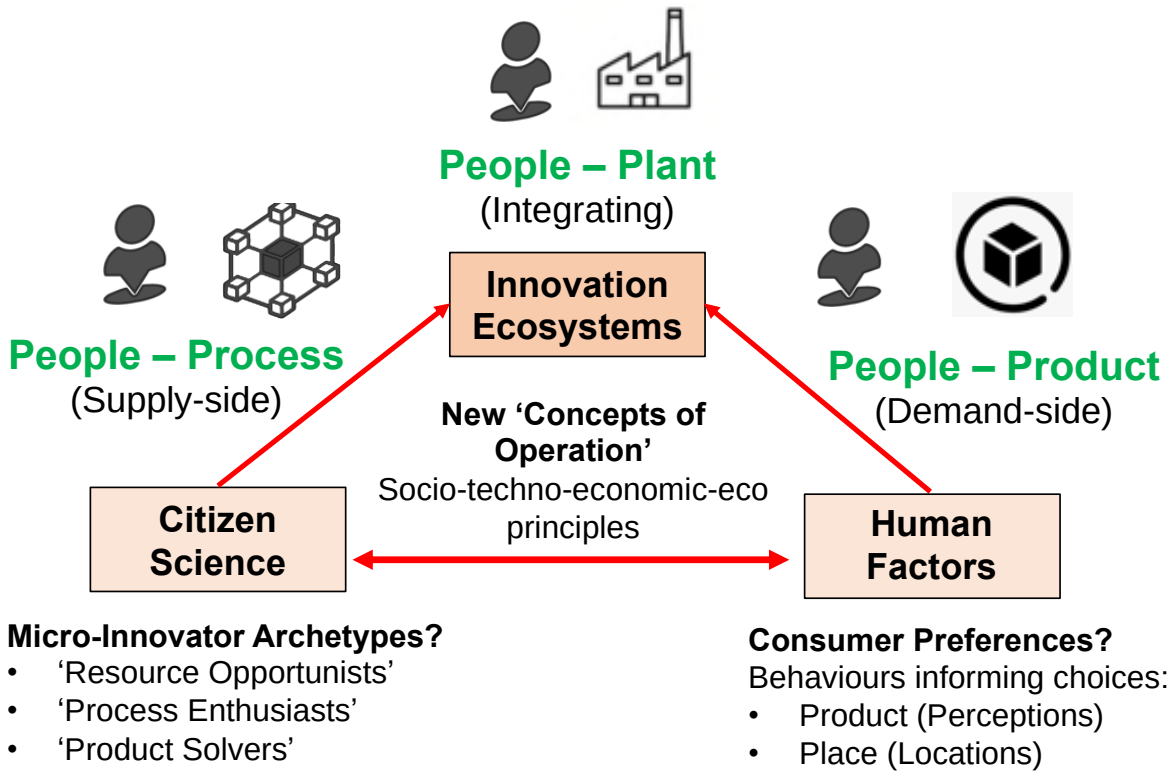

Figure 2. A vision of an Innovation Ecosystem (aligned citizen-led innovation and consumer acceptability to inform new 'concepts of operation')

Area of focus 1: Citizen Science (People-Process) draws on the philosophies of 'open science' (Smart et al., 2019) and 'collective intelligence' (Malone and Bernstein, 2015), to support the emergence of a network of citizen scientists to collectively solve intractable challenges in seaweed/circular bioeconomy settings. A methodology can leverage pre-competitive consortia research involving network partners collectively assessing new business models in different development–launch–supply scenarios and how they compare to existing conventional models (Srai et al., 2024; in review). This approach can be extended to help inform citizen scientists on appropriate business models as they build and test solutions.

Area of focus 2: Human Factors (People-Product) where experiments involving consumers should examine how end-users infer trade-offs between environmentalism and other product attributes. In addition, we should explore how changing consumer behaviour may influence future seaweed/circular bioeconomy product-service contexts, and reshape traditional operational practices and performance measures to include greater consumer participation, social considerations and multi-stakeholder service outcomes (Harrington et al., 2016).

Finally, an action research approach with methods for 'inclusive participation', that involve local innovation systems in the scaling of any appropriate solutions as part of:

Area of focus 3: Innovation Ecosystems (People-Plant). 'Assets-based science' thinking and programme research on 'farmer-producer organisations' (Harrington et al., 2023) could inform local capacity for innovation and new 'concepts of operation' (facilitating openness and effective 'co-production' between researchers, businesses, governments and end-user communities) that take advantage of local and regional capabilities (see deliverable 3.2 for the Norwegian maritime cluster).

Specifically, within regional innovation communities, we could look to target local fishing and agricultural value chains and engage with appropriate dissemination partners in running focused knowledge exchange events and challenge hackathons (e.g., through Hethel Innovation). For example, Hethel was previously involved in the establishment and running of 'Norwich Biomakers', a citizen science group looking at the cross-over of biology and technology to solve current challenges.

We should revive and engage with such citizen science communities on opportunities to develop solutions relating to seaweed/agile biorefining and enable them to access a network of assets, fab-labs and maker spaces (e.g., as per deliverable 5.1 but also Productivity East at UEA; the Ingenuity Lab in Nottingham; the Digital Innovation Facility at the University of Liverpool; and IfM Cambridge).

What a future work programme could look like (Deliverables D1-D6):

- **D1:** a draft open access-type 'asset library' of resources (data; equipment; fablabs; makerspaces) for use by citizens, entrepreneurs, SMEs, and regional innovation communities;
- **D2:** a 'concept of operations' to formalise an open science philosophy to guide stakeholders on available mechanisms for open science-human factors engagement;
- **D3**: an Innovation Ecosystem map linking individual citizens and specific communities and their experimentation activities to SEA project deliverables;
- **D4**: the extension of existing tools and approaches (and develop new tools where required) to educate stakeholders on consumer-centric supply network design; scaling of nascent and emerging science; and alternative scenarios from a demand-side perspective;
- **D5**: Design Rules development and the emergence of new operating principles, as inputs to sector-specific implementation guides;
- **D6:** Real-world application of outputs for business model validation of promising seaweed/circular bioeconomy designs and optimised network configurations for associated digital demonstrators

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