An underwater photograph showing a dense field of yellowish-brown seaweed (likely kelp) growing from a dark substrate. The seaweed blades are long and narrow, with some showing a distinct ribbed texture. The water is clear, and the background shows a bright blue sky through the water's surface.

Seaweed Aquaculture Industry Development

Business Case
South Coast Alliance Inc.
November 2021

Growing the economy while protecting local marine ecology



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The South Coast Alliance acknowledges the Noongar/Nyungar peoples of the South Coast region as the traditional custodians of this land and we pay our respect to their Elders past and present.



Growing the economy while protecting local marine ecology.

Seaweed aquaculture is attracting increased investment globally as it produces sustainable, high-value, nutrient dense foods, marine bioproducts and contributes to climate change mitigation and adaptation. The South Coast can grow a significant new industry using its existing assets including biodiversity, climate, geography and complementary industries. Research and development over the next three years could set the foundations for an industry worth up to \$515 million and employing 1054 people by 2030. While individual companies and investors are already progressing on seaweed opportunities in other locations, the South Coast is well-positioned to attract expertise and investment.

PROJECT DESCRIPTION

The South Coast of Western Australia has the biodiversity, geography, climate and complementary industries to capitalise on the emerging opportunities in seaweed¹ aquaculture² for commercial products, climate change mitigation and conservation benefits. There is a global wave of demand and associated research and investment in seaweed-related ventures and marine bioproducts.

Currently, Australia imports seaweeds for a range of uses – about \$40 million worth, 85% of which is for human consumption - and the local industry is relatively small: less than 40 direct full-time equivalent jobs (FTEs) and estimated \$3 million gross value of production (GVP). However, based on global and national precedents and a high-level investigation of the South Coast sites, species and potential proponents, the local industry could grow to \$541 million of output and 1,124 jobs by 2030.

The drivers of this opportunity include: climate change mitigation and adaptation, consumer demand for high-quality, sustainably-produced, nutrient-dense foods, science and technology enabling aquaculture in more locations and varieties, and the health and bioproducts of marine ecosystems being valued intrinsically and for the benefits they provide to existing industries.

Of all the opportunities associated with seaweed, these five are most relevant to the South Coast at this time:

1. *Asparagopsis* for use as a stock feed supplement for methane emissions reduction in cattle and sheep,
2. Red seaweeds for high-value nutraceuticals, pharmaceuticals, bioplastics and other marine bioproducts,
3. Green and red seaweed for human consumption, either fresh or processed,
4. In-situ ecological restoration of diverse seaweeds, especially kelp, for biodiversity conservation or as offsets for industry activities,
5. Brown seaweeds, such as kelp, for agricultural or domestic fertilisers.

Each of these opportunities has different merits, requirements, markets and constraints. Some of the species and technology are still in development or not yet commercially viable, however many commercial, social and political trends are converging to make seaweed an opportunity worth investigating. Each and all of the five opportunities could legitimately grow to be a significant industry.

The benefits to the South Coast beyond direct jobs and economic activity include: protection and restoration of globally-significant ecosystems, boosts to complementary industries such as boat building, processing, water transport and education, and contributing to the protection and sustainability of existing industries, such as agriculture, fishing and shellfish aquaculture.

There are several key gaps in information to quantify, qualify and progress the seaweed aquaculture industry. This business case details actions to identify the key: sites, species, commercial trials, markets, proponents, and technology that could enable seaweed aquaculture to be a significant new industry for the South Coast. Consultation with potential proponents revealed that most are early-

¹ By seaweed, we mean all forms of marine algae that live in the ocean and are visible to the human eye i.e. a range of red, brown and green macroalgae.

² By aquaculture, we mean breeding, raising and harvesting aquatic plants in the marine environment, including for the purposes of habitat restoration. This is the equivalent of farming, in the ocean, with some sort of intervention in the rearing process to enhance production e.g. stocking, feeding and protection from predators.

stage and not yet ready or able to proceed with a commercial project in the region, but that removal of key barriers could facilitate them moving or expanding into the South Coast.

Analysis of five different seaweed opportunities which have the potential for industry establishment in the region (at varying scales) indicates the following range of economic impacts for the Great Southern region by 2030³:

ADDITIONAL
**\$778 -
515M**
TOTAL OUTPUT

ADDITIONAL
**\$33 -
230M**
VALUE ADDED

ADDITIONAL
159-1124
JOBS

ADDITIONAL
**\$15 -
104M**
IN SALARIES & WAGES

³ Remplan 2021



MARKET CONDITIONS & PRECEDENTS

There are multiple markets for seaweed aquaculture, and for each of the five areas of opportunity. Below is an overview of the generalised supply chain, some key statistics across all seaweed, selected trends and cases within each area, and some specific precedents of relevant ventures or projects.

Demand conditions

The global commercial seaweed market size was US\$5.9 billion in 2019 with a projected compounding annual growth rate (CAGR) of 9.1% to 2027. Key drivers include technological developments in cultivating cultured seaweed, rising investments in application segments (including animal feed and agriculture), increasing awareness of health benefits, increasing demand for foods and snacks derived from commercial seaweed, demand for marine plant extracts (used as a thickening and gelling agents in the cosmetic and food industries), and alternative sources of feedstock for plastic production i.e. marine-derived bioplastics. Demand for seaweed as a sustainable product over the last decade has given rise to large scale on-land production facilities in Canada and ocean farms in the USA and Europe.

The Australian seaweed industry is small: currently valued at an estimated GVP of AUD \$3 million (2020), with the majority from one company; Kelp Industries Pty Ltd on King Island in Tasmania who collect storm-cast Bull Kelp for use in biofertiliser products. Australia seaweed imports in 2017/18 approached AUD \$40 million, of which 85% was for human consumption. Imports have been increasing, on average, at 15% per year, up from AUD \$17 million reported in 2008/09. Australia pays a high unit price for imported seaweed food products from China and South Korea.

Of the types of seaweed, red seaweed is the largest global product segment with a share of more than 50% in 2019, based on its varied application scope and easy availability. The South Coast has many endemic varieties of red seaweed, with very few being studied in-depth to understand their value and viability for aquaculture.

Brown seaweed is the second-largest global product segment with a share of over 45% and is used as food and raw materials for the extraction of hydro-colloid, alginate and liquid fertilisers. Brown seaweeds grow best in cold waters, up to about 20°C. The South Coast average sea temperature currently sustains brown seaweeds but may be impacted by climate change and make brown seaweeds less common in coming decades.

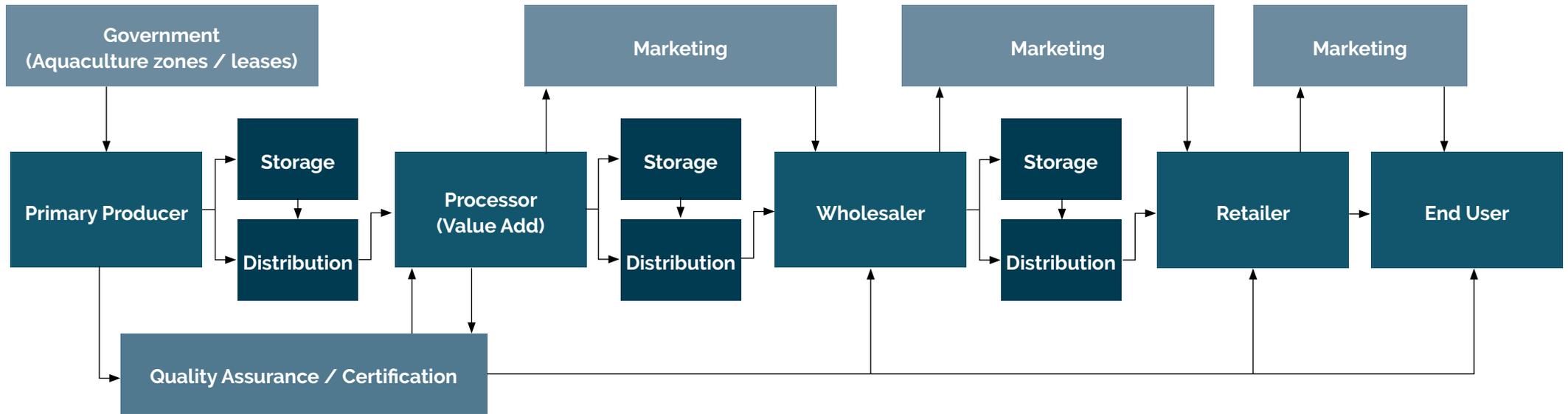
Of the forms of seaweed products, the commercial market is split into liquid, powdered, and flakes. The liquid sector is the largest, with a global revenue share of more than 52%; utilised as foliar fertilizer and soil conditioner. The powdered form of seaweeds are used as cosmetic and food products; used as scrubs, masks, and body wraps. The flakes form is widely used in the food industry. All forms, liquid, powdered and flakes, are experiencing strong growth in demand due to the increased valuing of their sustainability, nutrient density, and novel reasons specific to each application.

There are currently no commercially-producing ocean seaweed farms in Australia and only two small land-based operations for *Ulva* spp. cultivation in Shoalhaven, NSW (Venus Shell Systems) and Ayr, Queensland (Pacific Biotechnology). Both of these operations each have less than five hectares of seaweed under production. However, as illustrated by the precedents below, there has been a noticeable spike in licence applications and public and private investment in growing the industry and commercial trial projects. The industry size and stage of development in five years is likely to be very different from today.

Locally, there are significant opportunities for seaweed to add value to, or protect, existing industries: reducing the methane emissions of sheep and cattle, providing a substitute for fossil-fuel derived fertilisers, growing the supporting marine industries such as hatcheries and boat building, increasing the range of value-added food produced in the region, and conserving and enhancing the interesting experiences for tourists.

Supply chain

Figure 1 – Seaweed Aquaculture Supply Chain



To understand the seaweed aquaculture supply chain, it is important to consider significant differences compared to land-based agriculture, including:

- Proponents do not 'own' their sites for production, rather they have a license and / or lease. These take investment to obtain and there are limited suitable locations.
- The ocean is a more complex, costly, and risky area of operation than land. Advances in remote technology are making it more affordable and accessible.
- Site selection criteria varies across species. The conditions and operations for some species may be similar other aquaculture, like shellfish.
- Supply chains are generally not well established. The investment required to grow the industry (e.g. market development and infrastructure) are likely to be beyond the capacity of a single proponent to fund. Some key steps may also be restricted e.g., the IP for Asparagopsis processing is privately held.

Precedents

The precedents in the table below are illustrative of developments in different areas and stages of seaweed aquaculture, relevant to the South Coast.

PRECEDENT A – COMMERCIAL TRIALS FOR HUMAN CONSUMPTION	PRECEDENT B – COMMERCIAL ASPARAGOPSIS PRODUCTION	PRECEDENT C – SEAWEED FOR BIOPLASTICS
<p>Shoalhaven: Venus Shell Systems (NSW)</p> <ul style="list-style-type: none"> Commercial production of Ulva in ponds for human nutrition and health and wound treatment research Expansion plans Bluebiotech precinct established with Shoalhaven council as innovation precinct Phycohealth products include: chips, pasta, muesli, protein supplements, and dukkha <p>Bunbury: Indian Ocean Sea Vegetables (WA)</p> <ul style="list-style-type: none"> R&D into endemic species for human consumption Commencing commercial trials Applicable to South Coast 	<p>Triabunna: Sea Forest (Tas)</p> <ul style="list-style-type: none"> Sea Forest are first in the world to cultivate Asparagopsis at a commercial scale Using both marine and land-based aquaculture Planned commercial sales by 2022 Trial application as part of carbon-neutral wool production Raised \$34 million from investors including \$1 million from Australian Government <p>Cockburn: Fremantle Seaweed and Harvest Road (WA)</p> <ul style="list-style-type: none"> Fremantle Seaweed licence application for 100ha in Cockburn Sound, focused on seaweed Harvest Road approved for 100ha in Cockburn Sound for shellfish and seaweed 	<p>Waterman's Bay: Ullu (WA)</p> <ul style="list-style-type: none"> WA-based start-up company focused on bioplastics made from local seaweed Closed a funding round for \$1.3 million in September 2021 Trial and pilot products to be brought to market in 2022 Have already attracted international talent - three expert scientists - from overseas to work in the company Yet to determine source and location of seaweed feedstock, and South Coast is an option

Gaps and barriers

The top five gaps and barriers to be addressed at this stage, for the South Coast, are listed below. These gaps and barriers are typical of the early stages of industry development and each has the potential to be addressed through the planned actions and priority funding sources.

- Sites:** Uncertainty about site selection criteria and number of sites available,
- Species:** Uncertainty about which endemic species meet market needs, or may create new market opportunities,
- Markets:** Multiple potential commercial products and proponents, all relatively early-stage and with different scopes and requirements,
- Competition:** Competition with other aquaculture or other projects for leases, licenses, R&D, funding, or infrastructure including hatchery facilities,
- Capability:** Gaps in knowledge, technology, partners, or national / global market development to facilitate whole supply chain functioning.

A full list of gaps and barriers is outlined in appendix 1.



PROJECT RESOURCING, TIMEFRAMES, RISKS AND CONSTRAINTS

Resources and timeframes

The proposed approach is for staged investment in fundamental knowledge, support, and infrastructure for industry development, while at the same time supporting proponents to proceed with trials and commercial development. This logic is intended to support two pathways for industry development: one lead strongly by government and public institutions for regional economic and ecological benefit, the other being strongly led by industry proponents focused on commercial or conservation outcomes.

Table 1 – Proposed project resourcing and timeframes to unlock seaweed industry development

ACTIVITY	DESCRIPTION	EST. RESOURCING	YEAR 1	YEAR 2	YEAR 3
Site Investigation	Engage external consultant to conduct study, based on the 2018 South Coast Aquaculture Development Zone Site Investigation scope and methods. The output would be a report and site recommendations that could accelerate licences and leases, and recommendations for zone development.	\$50,000- \$70,000	\$50,000- \$70,000		
Species Shortlisting	Engage external consultant to review literature, engage with academics and commercial proponents to short list and prioritise species to focus on. The output would be a report on priority species and recommendations for how to maximise the value from them and priorities for further research.	\$40,000- \$60,000	\$40,000- \$60,000		
Market quantification	Consultant or contractor to identify local market opportunities for seaweed products, where they may complement or protect existing industries. The output would be a report and data for use by proponents in businesses cases and to attract investment.	\$40,000- \$80,000	\$20,000 -\$40,000	\$20,000 -\$40,000	
Industry development	Via a contractor or in-house, encourage commercial proponents to commence trials in this region e.g., Publish a webpage with contacts and key resources, facilitate forums, support funding applications, R&D connections, and licence applications. The outcome would be trials conducted as basis for full commercial projects.	\$60,000- \$90,000	\$20,000 - \$30,000	\$20,000 - \$30,000	\$20,000 - \$30,000
Supply chain facilitation	Consultant or contractor to review specific constraints to industry development, based on priority sites, species, markets, and proponents. The output would be businesses cases for infrastructure, advocacy, or investment.	\$40,000- \$60,000	\$10,000- \$20,000	\$30,000- \$40,000	
Infrastructure investment	New or upgraded infrastructure to support industry development. This may include expanded hatchery, onshore processing facilities or marine infrastructure.	Capital expenditure			To be determined
Total estimated resource requirements			\$230,000-\$360,000		

Risks

The following risks and management strategies have been identified for this project.

Table 2 – Potential project risks

RISK	DETAIL	PROBABILITY	CONSEQUENCE	MANAGEMENT
Competition for funding	Successful application for public funding will be competitive within the region, and across state and nation.	Almost certain	Minor	<ul style="list-style-type: none"> Engage with funding agencies early so they are aware of project. Invest in writing quality applications to ensure they are competitive.
Uncooperative proponents	Commercial proponents may not cooperate or co-invest with SCA, or other proponents.	Likely	Moderate	<ul style="list-style-type: none"> Engage with proponents to build trusted relationships. Provide value and adjust applications and projects to reflect their needs and input. Work with those who are cooperative and focused on whole industry development.
Viable industry	The sites or other immutable constraints prevent the industry being viable.	Possible	Major	<ul style="list-style-type: none"> Don't raise expectations of stakeholders or proponents. Ensure any studies and projects are comprehensive so there is no doubt as to results. Advance the work in steps and stages, with adequate resources.

ECONOMIC IMPACT

Australia currently imports almost all its seaweed requirements. Australia, and the South Coast, is potentially missing out on profiting from (and leading) an innovative, sustainable industry that has complementary benefits to other industries within the region, and Australia as a whole. By establishing seaweed production in the South Coast region there is the potential to create high quality jobs in aquaculture, offshore longline and rack aquaculture, agriculture and fishing support services, seafood processing, water transport, boat building and repair services and fish and seafood wholesaling.

Analysis of the five different seaweed opportunities which have the potential for industry establishment in the region (at varying scales) indicates the following range of economic impacts of the region by 2030:

Table 3 – Estimated regional economic impact of new seaweed production operations by 2030*

IMPACT AREA	DIRECT EFFECT	SUPPLY-CHAIN EFFECT	CONSUMPTION EFFECT	TOTAL EFFECT
Additional Output (\$million)	\$46 - \$323m	\$20 - \$140m	\$11 - \$77m	\$78 - \$541m
Additional Employment (Jobs)	85 - 597	44 - 319	30 - 208	159 - 1,124
Additional Wages and Salaries (\$million)	\$8 - \$53m	\$5 - \$34m	\$3 - \$18m	\$15 - \$104m
Additional Value-added (\$million)	\$18 - \$128m	\$8 - \$58m	\$6 - \$44m	\$33 - \$230m

Source: Remplan, 2021. *Economic impact analysis utilises the Great Southern region as a functional economy. Ranges in table describe low and high production capacity potential across five different seaweed species or groups. See appendix 1 for a glossary of economic terms and appendix 4 for further details of the economic impact analysis.

The establishment of regional seaweed production also has the following potential indirect benefits:

- **Regional leadership and cluster development** – The seaweed industry in Australia in 2021 is small, relative to other countries. The south coast of Western Australia has been identified as a key location with immediate potential for development of sizeable industries within the next five years, which provides a unique opportunity to establish the region as an industry development leader in Western Australia, and even nationally.
- **Aquaculture innovation and human capital development** – The establishment of a variety of seaweed variety productions in the region, supported by co-location of research institutes such as the University of Western Australia’s Great Southern Marine Research Facility as well as other aquaculture businesses and projects (i.e. Albany Shellfish Hatchery and Bremer Bay’s 888 Abalone), presents opportunities for research and development and innovation to identify efficiencies in seaweed development processes and value-add opportunities. As the industry grows, its interaction with other regional businesses and supply chains also has the potential to develop knowledge, skills and talent (human capital) that are unique to the South Coast region, increasing the region’s competitive advantage and attracting high quality jobs and expertise to the area.



FUNDING AND INVESTORS

Positioning

The South Coast has been identified in national studies, state government reports and by commercial proponents as a high-potential site for seaweed aquaculture. The biodiversity, climate, sites, and infrastructure mean it is well-positioned to lead the growth of this industry in Western Australia, if not more widely. Now is a very timely opportunity to work with stakeholders from across academia, government, and business to advance the necessary research and development to grow this industry. Ten potential commercial proponents were engaged with in this project. Several have expressed interest in co-investing in the proposed next actions.

Strategy

Undertaking some fundamental studies, engagement and facilitation of collaboration could rapidly accelerate industry development. No one proponent has the resources to investigate all potential sites, species, markets and supply chain restrictions. The SCA can partner with other levels of government and industry to attract funding and do the work that reduces the risks and uncertainties for business and investors. In addition, synergies can be explored with other industries, and advance the positioning of the region as a leader in blue, green, sustainable and innovative industries.

Funding and investment

Commitment of time, and some cash, from local government and some commercial proponents is necessary to attract matching public funding. The SCA and individual local governments could assist through auspicing initial funding applications, contributing matched funding, and providing points of connection between stakeholders e.g., proponents, researchers, investors, agencies, businesses. Beyond initial projects the industry development may be advanced by individual businesses, or in cooperation with other institutions like the Aquaculture Council of WA or Marine Bioproducts CRC. Local SMEs would likely be the primary source of private investment in initial phases, though individual products, ventures, or infrastructure may attract private equity or debt funding.

The top four sources of possible funding are identified in table 4. See appendix 5 for the full prioritised list of relevant funding. The list of potential private investors, including charitable organisations is extensive and is not included on the table on the next page.

Table 4 – Shortlisted potential funding sources

FUNDER*	WHAT THEY FUND / RELEVANCE	\$ AVAILABLE	PRIORITY	SUGGESTED NEXT ACTION
Regional Economic Development Grants	For plan, SMEs and specific projects: invests in community-driven projects that support efforts to create long-term economic growth and job sustainability in regions. Matched dollar-for-dollar.	Up to \$250,000 per project	H	Engage with GSDC and apply for future rounds.
Regional New Industries Fund	For plan and SMEs: provide grants across the nine regions of Western Australia to support venture creation, accelerate small-medium enterprise growth and seed innovation initiatives.	No maximum, but likely less than \$250,000 per project.	H	Engage with DPIRD to position for when new rounds announced.
Building Better Regions Fund	For plan: create jobs, drive economic growth, and build stronger regional communities into the future. Focused on new or expanded local events, strategic regional plans or leadership and capability strengthening activities. Matched dollar-for-dollar. Other stream available for infrastructure.	Up to \$10million per project	H	Engage with Australian Government to position for when new rounds announced.
Cooperative Research Centres Projects (CRC-P) Grants	For SMEs: short-term (up to 3 years), industry-led collaborations to: <ul style="list-style-type: none"> • develop a product, service or process that will solve problems for industry and deliver real outcomes • benefit small to medium enterprises (SMEs) • include education and training activities. 	Up to \$3 million per project	M	Encourage SMEs to engage with Australian Government representatives and apply prior to November 16 deadline, or position for future rounds.

* Funder names include hyperlinks to relevant websites.

STAKEHOLDERS & CALL TO ACTION

Strong stakeholder engagement and collaboration will be critical to progress this opportunity.

Table 5 – Project stakeholders and potential roles in the project

STAKEHOLDER NAME	POTENTIAL ROLE
DPIRD (including Great Southern Development Commission, Trade and Investment and Aquaculture branches)	<ul style="list-style-type: none"> • Invest funding into industry development and specific projects through competitive funding rounds • Collaborate on research into sites, species and markets • Be clear, encouraging, and efficient in responding to aquaculture license applications
Aquaculture Council of Western Australia	<ul style="list-style-type: none"> • Collaborate on research, funding applications and advocacy / awareness-raising • Support South Coast industry development through advocacy
Individual aquaculture proponents	<ul style="list-style-type: none"> • Collaborate and co-invest in research, funding applications and advocacy / awareness-raising • Follow-through on expressed interest in developing operations on the South Coast
South Coast Alliance	<ul style="list-style-type: none"> • Facilitate or auspice initial funding applications • Act as a convenor or facilitator of key stakeholders during industry development
Local government	<ul style="list-style-type: none"> • Auspice or co-invest in funding applications • Collaborate with industry and other stakeholders on land-based aspects of projects
Local industry	<ul style="list-style-type: none"> • Consider opportunities to supply or use seaweed within supply chain • Be responsive to opportunities to supply the aquaculture industry
Local community	<ul style="list-style-type: none"> • Support industry development where it aligns with (and doesn't contradict) community vision



Investing in research and development for seaweed aquaculture could create the foundations for a significant new industry on the South Coast. Seaweed aquaculture aligns strongly with the vision and values of the region's institutions and community: it builds on regional assets, contributes to the protection and sustainability of both ecological systems and existing local industries. There are a diverse range of potential project proponents and seaweed uses. The initial research into sites, species, markets, and technology could facilitate rapid and large-scale private investment.

**For more information about this opportunity, contact the South Coast Alliance Executive Officer:
ceo@southcoastalliance.org.au**

Appendices list – Seaweed Industry Development

1. Gaps and barriers – full list
2. Glossary of economic development terms
3. Economic impact analysis – Additional detail
4. Funding sources – Additional detail
5. Market analysis – Additional detail

Appendix 1 – Gaps and barriers – Full list

Table 5 – Full list of gaps and barriers

Gaps and Barriers	Role of Government / Advocates
Seaweed is not embraced as a serious aquaculture industry in Australia.	<ul style="list-style-type: none"> Advocate for seaweed to be included in relevant Federal and State Government agriculture, aquaculture, biotechnology, and advanced manufacturing development strategies. Advocate for the seaweed sector to be recognised as a major contributor to the National Aquaculture Strategy and allocate funding for its development.
Markets and supply chains not yet proven.	<ul style="list-style-type: none"> Assist prospective investors / producers to focus on cultivation of known species and development of food, feed or fertiliser products into existing markets and evolve new products over time.
Limited availability of commercial scale ocean leaseareas in most State and Commonwealth waters.	<ul style="list-style-type: none"> Initial focus of industry development in a few key States where ocean leases are available already. Albany Aquaculture Development Zone Stages 1 and 2 are prime locations but are limited to shellfish aquaculture only. Engage locally and regionally with existing aquaculture lease holders and Indigenous groups and other industry groups e.g., oyster industry. Work with other States and Commonwealth on areas where seaweed ocean leases could be made available in future.
Regulation and licensing of seaweed aquaculture is complex, onerous and different in each State.	<ul style="list-style-type: none"> Work with regulators in jurisdictions where demonstration farms can go ahead and where cultivation manuals can be developed for target species to evolve policy and regulation.
Shortage of people with skills, knowledge and practical experience specific to seaweed Aquaculture.	<ul style="list-style-type: none"> Advocate for and assist in the establishment or promotion of training and development programs. Engage with existing aquaculture operators, Indigenous groups and parallel industry groups on training and development program at national, regional, and local levels. Assist in attracting talent from other countries which will be suffering from continued uncertainty associated with COVID-19; technology transfer from overseas, from areas where seaweed farming is well developed, is an important way of facilitating rapid development. Assist in the development of cluster plans to drive supply chain development in these areas.
Lack of funding for R&D and limited collaboration between commercial and research entities	<ul style="list-style-type: none"> Significant funding is needed for critical path RD&E for seaweed industry development. Government funds are needed for the firsttwo years of RD&E until the industry could potentially become levy paying. Advocation for government funds to support the industry required.
No commercial scale hatcheries/ seedbanks.	<ul style="list-style-type: none"> Advocate for the establishment of a nationally-owned Temperate and Tropical Seedbank / Hatchery network that could provide seeded rope to accelerate new project developments.
Gaps in breeding and cultivation knowledge for many species e.g., <i>Asparagopsis</i> .	<ul style="list-style-type: none"> Advocate for increased investment in breeding and cultivation techniques for promising species like <i>Asparagopsis</i>.
Biosecurity – currently limited knowledge on nativeseaweed populations and concerns about translocation of seedstock, pests and disease.	<ul style="list-style-type: none"> A lot of work exists internationally on seaweed biosecurity risks and issues, and this could be a starting point to highlight gaps in the Australian context. Assist investors / producers to focus on endemic species and implement adaptive management plans for early operations.
Social license concerns.	<ul style="list-style-type: none"> Raise public awareness about the benefits of seaweed aquaculture, the nutritional profile of the products and the contribution of the industry economically, socially, and environmentally. Advocate for / facilitate development of environmental standards for management and monitoring seaweed ocean aquaculture.

Appendix 2 – Glossary of terms

Table 6 – Glossary of Economic Development Terms

Additional Output / Output effect	Additional economic output (i.e., business conducted) in dollars due to changes to a particular industry or business.
Additional Employment	Additional jobs created due to changes to a particular industry or business.
Additional Wages and Salaries	Additional wages created due to changes to a particular industry or business, due to either to new jobs being created, or changes to existing jobs resulting in pay rises due to higher skillsets being required.
Additional Value-added	The increase in value (measured in dollars) that a business or industry creates by improving an input product (for example, adding value to wheat by baking it into bread).
Consumption	The act of goods and/or services bought by people, with value measured in dollars.
Consumption effect	Measures the change in consumption for all goods and services arising from the increase in output (i.e., the increases in good or services being produced).
Direct impact	The impact that directly results from changes to a particular industry or business. Can apply to jobs, output, wages, etc.
FTE (Full Time Equivalent)	The equivalent of one person working full time (for example, two part time employees may make up the hours of one FTE).
Indirect impact / Supply chain effect	Refers to the impact that changes to a particular industry or business create <i>indirectly</i> on all stages of the supply chain. Essentially a “ripple effect” of the direct impact.
Supply Chain	A network between a company and its suppliers that shows how a specific product or service is made and then distributed to the final consumer.

Appendix 3 – Economic impact analysis – Additional detail

Methodology:

Economic impact analysis conducted utilised a ‘goal seek’ approach to identify the potential impacts of investment in five different species of seaweed (see table 7). The analysis drew on available information regarding:

- Potential area or amount of production (ha);
- Capital expenditure required to establish and produce; and
- Potential new jobs enabled by enterprise establishment or expansion.

This information was analysed by a regional input output model to produce potential additional output, employment, wages and salaries and value add to the regional economy by the year 2030. While this project is focused on the four South Coast Alliance councils, economic impact analysis utilise the Great Southern region as a functional economy, recognising that impacts and supply chains are likely to involve other centres throughout the Great Southern region. In addition, potential funders are likely to recognise the Great Southern region as a functional economy and utilise aligned data for their own assessment and impact reporting.

Table 7 – Seaweed species assumptions utilised for impact analysis (input output).

Seaweed	Low (ha)	High (ha)	Low (\$)	High (\$)
Asparagopsis	10	100	\$10,000,000	\$30,000,000
Red seaweeds for high-value nutraceuticals or other marine bioproducts	1	10	\$1,000,000	\$5,000,000
Green and red for consumption	1	10	\$1,000,000	\$5,000,000
Diverse seaweed species for offset and ecological restoration	10	100	\$1,000,000	\$10,000,000
Brown Seaweed	1	10	\$1,000,000	\$10,000,000
Seaweed summary	Low FTE	High FTE	Low CAPEX	High Capex
Per hectare for new lease	23	230	\$14,000,000	\$60,000,000
Per h of production	11.5	115	\$7,000,000	\$30,000,000
per h for development on existing areas	5.75	57.5	\$ 3,500,000	\$15,000,000
Total	40	403	\$24,500,000	\$87,500,000

Source: For Blue, 2021 (see sources list for further detail).

Table 8 – Input output analysis – low and high range production potential, estimated impact from direct jobs by 2030.

Seaweed (low)	Impact Area	Direct Effect	Supply-Chain Effect	Consumption Effect	Total Effect
	Additional Output (\$M)	\$21.67	\$9.46	\$5.35	\$36.48
Additional Employment (Jobs)	40	21	14	75	
Additional Wages and Salaries (\$M)	\$3.59	\$2.28	\$1.24	\$7.11	
Additional Value-added (\$M)	\$8.67	\$3.97	\$3.05	\$15.69	
Seaweed (high)	Impact Area	Direct Effect	Supply-Chain Effect	Consumption Effect	Total Effect
	Additional Output (\$M)	\$218.36	\$95.32	\$53.85	\$367.52
Additional Employment (Jobs)	403	208	140	751	
Additional Wages and Salaries (\$M)	\$36.16	\$22.97	\$12.48	\$71.61	
Additional Value-added (\$M)	\$87.39	\$39.96	\$30.76	\$158.11	

Source: Remplan, 2021. * Economic impact analysis utilises the Great Southern Region as a functional economy

Table 9 – Input output analysis – low and high range production potential, estimated impact from capital expenditure by 2030*

Seaweed (low)	Impact Area	Direct Effect	Supply-Chain Effect	Consumption Effect	Total Effect
	Additional Output (\$M)	\$24.50	\$10.70	\$6.04	\$41.24
Additional Employment (Jobs)	45	23	16	84	
Additional Wages and Salaries (\$M)	\$4.06	\$2.58	\$1.40	\$8.03	
Additional Value-added (\$M)	\$9.81	\$4.48	\$3.45	\$17.74	
Seaweed (high)	Impact Area	Direct Effect	Supply-Chain Effect	Consumption Effect	Total Effect
	Additional Output (\$M)	\$105.00	\$45.24	\$23.38	\$173.62
Additional Employment (Jobs)	194	111	68	373	
Additional Wages and Salaries (\$M)	\$17.11	\$10.71	\$5.22	\$33.04	
Additional Value-added (\$M)	\$40.44	\$18.44	\$13.27	\$72.15	

Source: Remplan, 2021. * Economic impact analysis utilises the Great Southern Region as a functional economy

Sources:

- World Bank Group, 2016. Seaweed Aquaculture for Food Security, Income Generation and Environmental Health in Tropical Developing Countries. World Bank. <https://doi.org/10.1596/24919>
- Agri-Futures Australia (2020) Australian Seaweed Industry Blueprint – A Blueprint for growth. agrifutures.com.au
- Remplan, 2021

Appendix 4 – Market analysis – Additional detail

Factor conditions

Seaweed is grown predominantly on commonly used aquaculture infrastructure of long lines, floating nets or rafts in China, Japan and South Korea or in more basic, 'off the bottom' farming systems in Indonesia, Philippines and Tanzania. Booming demand for seaweed as a sustainable product over the last decade has given rise to large scale on- land production facilities in Canada and ocean farms in the USA and Europe.

Despite being well behind Asia, these emerging seaweed industries in the USA, Europe, Scandinavia and Chile are five to ten years ahead of Australia and could provide many relevant insights. For example, GENIALG, a three-year, \$16 million project aimed to boost the European Blue Economy, by designing high-yielding seaweed cultivation systems for two species, will conclude later this year.¹

Market conditions

The global commercial seaweeds market size was calculated to be at USD 5.9 billion in 2019 and is anticipated to witness a CAGR of 9.1% to 2027. Technological developments in cultivating cultured seaweed coupled with rising investments in application segments, including animal feed and agriculture, are likely to propel market growth in the coming years. Increasing awareness pertaining to the health benefits of the product coupled with increasing demand for foods and snacks derived from commercial seaweed is estimated to boost the human consumption application segment. The swelling demand for marine plant extracts, used as a thickening and gelling agents in the cosmetic and food industries, is also likely to boost growth, primarily in North America and Europe.

In 2019, red seaweed was the largest product segment with a share of more than 50.0%. The segment is projected to expand at the fastest CAGR in the coming years. Red seaweed is used in numerous sectors on account of their excellent functional attributes. They are utilized as food crops offering high quantities of vitamins and proteins. Varied application scope coupled with easy availability of red seaweed is likely to drive the segment.

Brown seaweed was the second-largest product segment in 2019 with a share of over 45.0%. Mainly, brown seaweeds are used as foods and as raw materials for the extraction of hydrocolloid and alginate. The brown seaweeds are more useful and grow in cold waters in both the Northern and Southern Hemispheres. They thrive best in waters up to about 20°C. Brown seaweeds are found in warmer waters, but these are less suitable for alginate production and are rarely used as food.

¹ Jo Kelly, Australian Seaweed Institute, Australian Seaweed Industry Blueprint: A Blueprint for Growth, August 2020

Based on form, the commercial seaweeds market has been bifurcated into liquid, powdered, and flakes. In 2019, the liquid commercial seaweed emerged as the largest segment with a revenue share of more than 52.0%. The liquid form of commercial sea vegetables is utilized as foliar fertilizer and soil conditioner for plants to provide minerals, vitamins, potassium, and enzymes that accelerate plant growth.

Seaweed extracts are marketed as biostimulants and liquid fertilizers since they comprise many growth regulators such as auxin, betaines, cytokinins, gibberellins, and macronutrients including K, Ca, and P, and micronutrients including Cu, B, Fe, Zn, Mn, Co, and Mo. Growing product demand as biostimulants and insecticides for plant growth is estimated to boost its growth over the forecast period.

The powdered form of commercial sea vegetables is utilized in the human consumption application segment as cosmetic and food products. They are used as scrubs, masks, and body wraps. Rapidly expanding application industries, including food and beverage and cosmetics, along with increasing focus of consumers on beauty and health are projected to drive the segment.

Commercial seaweed in the form of flakes is widely used in the food industry. Increasing demand for organic food products is likely to boost segment growth. The nutritional value of commercial seaweed stays undamaged in flakes, which makes it suitable for consumption in the food processing industry. Dulse flakes are employed in cheese, salad, hummus, and condiment.²

As identified by Kelly (2020)², the Australian seaweed industry is small: currently valued at an estimated GVP of AUD \$3 million. Of this, the majority is from one company, Kelp Industries Pty Ltd on King Island in Tasmania, who collect storm-cast Bull Kelp (*Durvillea potatorum*) predominantly for export to a large alginate manufacturer and for use in biofertiliser products. Australia Bureau of Statistics (ABS) data shows seaweed exports from Australia are valued at \$1.5 million for non-human consumption and it is assumed that this is almost entirely from Kelp Industries exports. However, Australia is a net importer of seaweed. Annual imports to Australia in 2017/18 approached AUD \$40 million, of which 85% was for human consumption. Imports have been increasing, on average, at 15% per year, up from AUD \$17 million reported in 2008/09.

Australia pays a high unit price for imported seaweed food products from China and South Korea. There are currently no commercial ocean seaweed farms in Australia and only two small land-based operations for *Ulva* spp. cultivation in Shoalhaven, NSW (Venus Shell Systems) and Ayr, QLD (Pacific Biotechnology). Both of these operations each have less than five hectares of seaweed under production.

Besides Kelp Industries, other seaweed collectors in Tasmania include Kelpomix and TasKelp. There is a license for small scale collection of Golden Kelp (*Ecklonia radiata*) in NSW at Narooma where it is dried and turned into food products at Sea Health Products. Additionally Great Gather Ocean Group, is a Chinese owned company, which has a South Australia based beachcast seaweed business at Millicent in the south-east of the state. There are also licenses

² <https://www.grandviewresearch.com/industry-analysis/commercial-seaweed-market>

for wild harvest of the invasive species of *Undaria* in Tasmania (KaiHo Ocean Treasure) and some in Victoria. Based on information provided in stakeholder interviews and publicly available, it is estimated that there are approximately 20 full time equivalents (FTE) directly employed in commercial seaweed cultivation in Australia.

Collection of seaweeds is currently the main source of Australian seaweed today, however, there are a number of limiting factors for collection of seaweeds including availability of beach-cast seaweed, quality, seasonality, community concerns and permitting. Wild harvest of seaweed from in-sea is of concern due to the lack of information on its potential to regrow and other potential environmental impacts. Therefore, the report does not further consider the growth of this sector given the very limited opportunity from an economic, social and environmental perspective.

Two Australian seaweed product manufacturers of note are Seasol, who make a biofertiliser from Australian Bull Kelp, and Marinova who manufacture fucoidan extract from largely imported seaweeds for the health and nutrition market. There are also a small number of boutique food product producers using some Australian and imported seaweeds, such as Alg Seaweed.

Past Australian research on seaweeds is considerable although fragmented and it was generally recognised by key stakeholders interviewed that there is a lack of biological knowledge on most species which is critical in underpinning the success of an emergent cultivation industry. Previous AgriFutures Australia reports have focussed predominantly on applications of seaweeds for food, the nutritional properties of a limited number of species, and quality control in production (Lee, 2008; Winberg et al., 2008).

Currently the industry largely consists of seaweed scientists and researchers with an estimated 30 – 40 FTE roles spread across several research institutions nationwide. Australia currently has no centralised research hub for marine plants or bioproducts. Most seaweed expertise resides at marine research or biotechnology departments at several universities, Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Australia Institute of Marine Science (AIMS).

While there are numerous research projects taking place or being planned, the only lines in the water that are growing seaweed at the time of the Australian Seaweed Industry Blueprint's publication are two projects in Tasmania. The first project is a CRC-P project involving collaboration with Tassal, Spring Bay Seafoods and University of Tasmania (UTAS) and is expected to reap their first harvest later this year. This project aims to demonstrate the benefits of Kelps as part of an integrated multitrophic aquaculture (IMTA) approach. The second is a research collaboration between UTAS and Huon Aquaculture in Storm Bay that will also yield its first harvest in late 2020.

In stakeholder interviews, most State Government aquaculture regulators, with the exception of Northern Territory and Victoria, reported a significant increase in parties interested in obtaining aquaculture licenses for seaweed ocean farms. The Climate Foundation's seaweed permaculture concept and

upwelling technology gained a lot of public interest following the documentary 2040 and close to \$600,000 was crowdfunded for a small technology pilot focussed on Kelp production in Tasmania.

But much of the recent commercial interest has been sparked by the discovery that a group of native Australian seaweeds, *Asparagopsis* spp., can reduce the methane emissions from cattle by 99% when as little as 2% is added to their feed (Kinley et al., 2016; Machado et al., 2016). This discovery is being commercialised by FutureFeed Pty Ltd, which was established by CSIRO to hold the exclusive rights to the patents from CSIRO, James Cook University and Meat and Livestock Australia

Appendix 5 – Additional potential funding sources

Table 10 – Additional potential funding sources

Funder	What they fund / relevance	\$ available	Priority	Suggested next action
Regional Economic Development Grants	For plan, SMEs and specific projects invests in community-driven projects that support efforts to create long-term economic growth and job sustainability in regions. Matched dollar-for-dollar.	Up to \$250,000 per project.	H	Engage with GSDC and apply prior to October 21 deadline, or position for future rounds.
Cooperative Research Centres Projects (CRC-P) Grants	For SMEs: short-term (up to 3 years), industry-led collaborations to: <ul style="list-style-type: none"> - develop a product, service or process that will solve problems for industry and deliver real outcomes - benefit small to medium enterprises (SMEs) - include education and training activities. 	Up to \$3 million per project.	H	Encourage SMEs to engage with Australian Government representatives and apply prior to November 16 deadline, or position for future rounds.
Regional New Industries Fund	For plan and SMEs: provide grants across the nine regions of Western Australia to support venture creation, accelerate small-medium enterprise growth and seed innovation initiatives.	No maximum, but likely less than \$250,000 per project.	M	Engage with DPIRD to position for when new rounds announced.
Grants for Asian Export Market	For SMEs: to better equip WA agrifood exporting businesses to develop and implement strategies to capture export market opportunities and attract investment. Matched dollar-for-dollar.	Up to \$50,000 per application	M	Encourage SMEs to apply.
Value Add Investment Grants	For SMEs: to boost local food and beverage manufacturing and value adding. Focused on	Up to \$750,000 per application	M	Encourage SMEs to apply.

	capital expenditure for expanding or relocating value-adding in WA. Matched dollar-for-dollar.			
Coles Nurture Fund	For SMEs: Help producers, farmers and manufacturers to innovate and grow their business. Focused on differentiation, sustainable practices, extending growing seasons, improving productivity and reducing imports.	Up to \$500,000 per application	M	Encourage SMEs to apply.
Export Market Development Grants	For SMEs helps grow their exports in international markets through marketing and promoting their goods and services globally.	Up to \$150,000 per year, for up to three years	M	Encourage SMEs to apply.
Growth Grants	For SMEs: help improve specific business areas to improve the ability and skills of your business to trade. Matched dollar-for-dollar.	Up to \$20,000 per application	M	Encourage SMEs to apply.
Agrifood and beverage voucher program	For SMEs: to engage a consultant or technical expert to help grow their business through: <ul style="list-style-type: none"> - Business planning - Manufacturing - Sales and marketing - Financial health - Environmental sustainability and social responsibility Matched dollar-for-dollar.	Up to \$15,000 per business.	M	Encourage SMEs to apply.
Innovation Connections	For SMEs: to research an idea with commercial potential with the support of a facilitator and pairing with a researcher.	Up to \$50,000 per application	M	Encourage SMEs to apply.

Export Finance Australia	For SMEs: financial expertise and solutions including loans, guarantees, bonds and insurance focused on enabling SMEs to realise export opportunities or contribute to the export supply chain.	Not specified	L	Encourage SMEs to apply.
Marine bioproducts CRC	For planning or SMEs: seek partnerships from within this consortium of industry, government and research partners. All focused on growing the export-focussed marine bioproducts industry.	Not specified	L	Engage

Hyperlinks have been included in the funder titles.