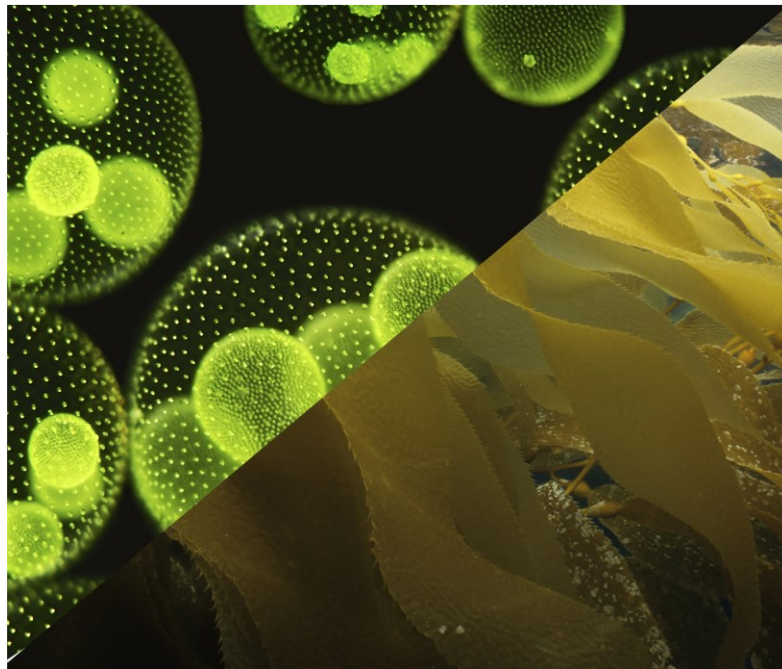


Algal Bioenergy Special Interest Group

Status update on recommendations from The UK Roadmap for Algal Technologies

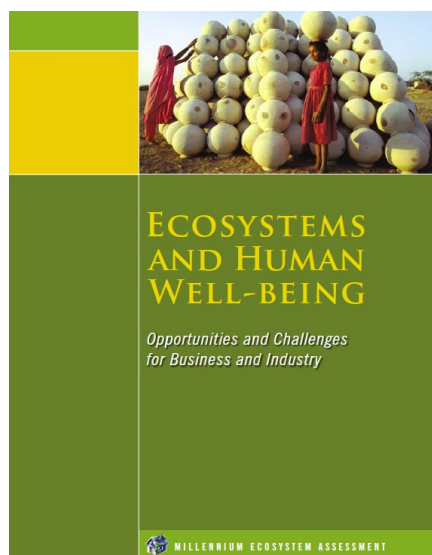
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1. Introduction and Background

[The UK Roadmap for Algal Technologies](#), published in 2013 (Schlarb-Ridley & Parker, 2013), was commissioned by the Algal Bioenergy Special Interest Group ([ABSIG](#)) to understand the commercialisation potential of algae-related products, processes and services for the UK. The report highlights activities, which are on or close to market, are under development, require more R&D or have the highest potential for the UK plus the interventions required to realise them.

The objective of this short report is to assess the progression made by stakeholders in delivering the main recommendations identified in the Roadmap and identify areas requiring further action. The Natural Environment Research Council ([NERC](#)) and [Innovate UK](#) sponsor the ABSIG and are the main stakeholders in the UK for ensuring cohesion and progression towards the commercialisation of algae products, processes and services. The ABSIG is therefore tasked with ensuring progress is made and that mechanisms are in place to facilitate progression.



1.2 The Algal Bioenergy Special Interest Group (ABSIG)

Initiated in 2011, the role of the ABSIG is to liaise with government and other stakeholders to ensure strategies are in place to enable project developers to maximise the opportunities available towards creating a sustainable algae-based industry in the UK. The role of algae as a tool in ecosystem services is a key focus area for the ABSIG as algae can play essential roles in the provisioning; regulation and supporting of resources humans need to survive. Also, businesses wishing to create an industry from algae need to understand the environmental impacts

their activities could have and the subsequent implications to their business models. The [Millennium Ecosystem Assessment](#) and the [UK National Ecosystem Assessment](#) are good resources for businesses to help them integrate ecosystem services considerations into their business models.

The ABSIG is managed by the Knowledge Transfer Network Ltd. (KTN) and has a strong company engagement strategy at the core of its objectives. Having a clear understanding of the algae capabilities in the UK is essential in the provision of facilitation and building of strategic partnerships. It is through cohesion and connectivity that businesses can grow and innovate.

The Special Interest Groups are intended to have a defined lifespan and as such the ABSIG, as a dedicated programme of activity, ended on 31st March 2016. KTN will continue to facilitate commercialisation and innovation in algae technologies in partnership

with Innovate UK and Business, Innovation and Skills. The team can still advice on funding, make connections, critique funding applications and participate in strategic activities, including supporting the actions identified in the Roadmap.

Section 2 reviews the identified enablers and recommendations from the Roadmap and where possible, offer an update on progress and suggest actions for further progression.

2. A UK Roadmap for algal technologies: An update

2.1 Roadmap Recommendations

The Roadmap is intended to offer an overview of current capabilities in the UK and identify the near, mid- and longer-term opportunities where the UK can make impact.

Much of the algae expertise in the UK is in academia whilst much of the business activity is focused on bioremediation and the extraction of omega oils for the health and

nutraceutical market in the context of microalgae applications and food and fertiliser for macroalgae (Figure 1).

The most commercially promising areas identified in the roadmap include:

Short to medium term:

- High value products from both macro – (condiments and premium sea vegetables, high value uses of hydrocolloids) and microalgae (increased production of established and emerging bioactives, e.g., DHA, EPA, pigments, antioxidants, sunscreens)
- Bioremediation using macro- and micro- algae linked to feed and fertiliser production and decentralized

energy generation via anaerobic digestion

- Knowledge industries for technology provision and consulting

In the medium to long term:

- Integrated biorefining of micro- and macroalgae coupled to fractionation or thermochemical conversion for a suite of chemical and energy products
- Novel bioactives through bioprospecting (micro- and to some extent macroalgae) and metabolic engineering (microalgae) for pharma, cosmetics, nutrition



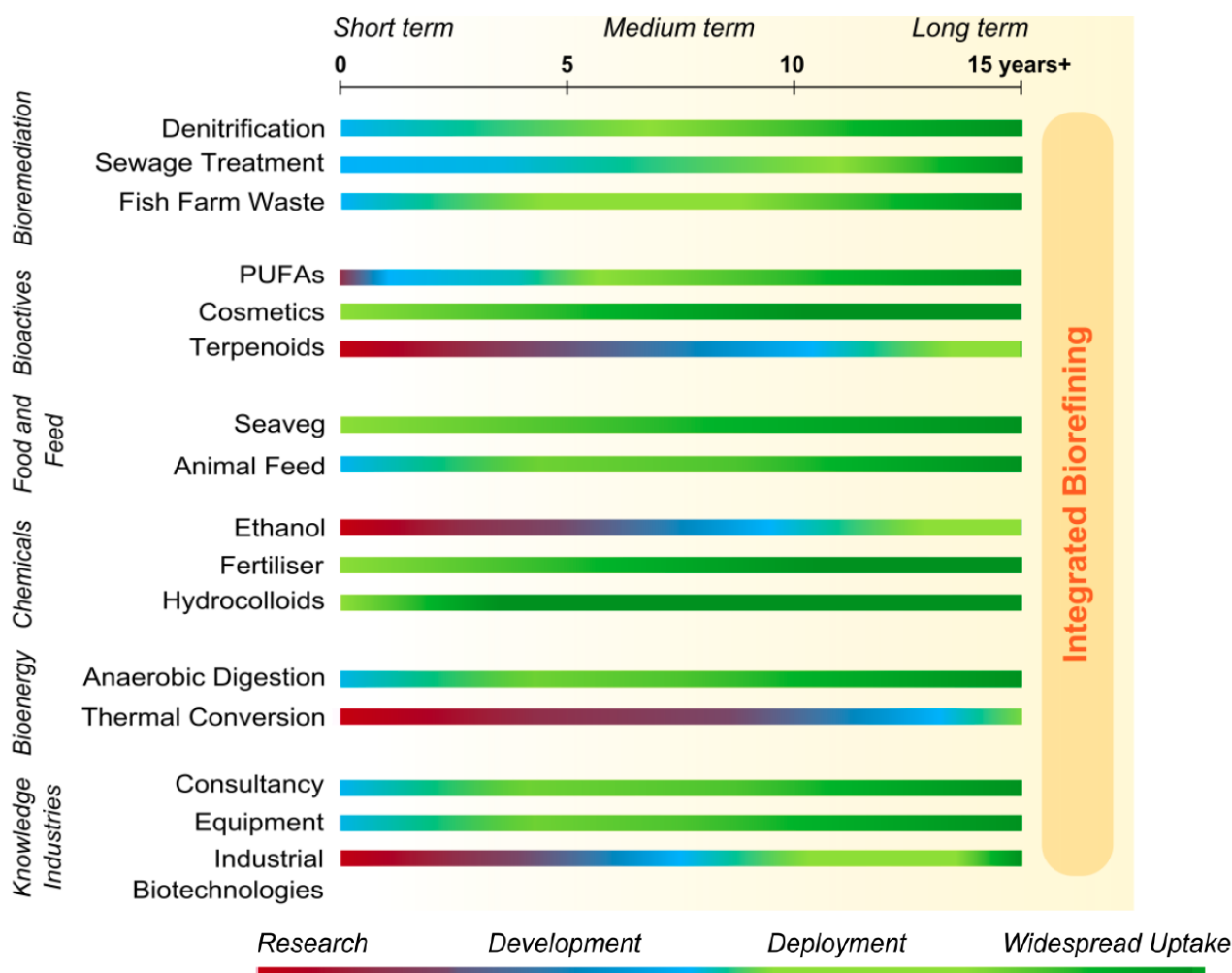


Figure 1. Indicative timescales to commercialisation for micro – and macro-algae products and processes.

The Roadmap identified four key enablers to realising the short, medium and longer-term opportunities: Technical, Financial, Services and Regulation. Table 1 lists the identified enablers and offers a status update and a proposed action for each.

Table 1. Key enablers identified in the Roadmap required to realise the short, medium, and longer-term opportunities.

Identified enablers		Status	Proposed action
Technical	Accessible test/pilot/demonstration facilities to collect data on ecological impact, operational costs, life cycle parameters and variability of yields, all of which underpin developing business case scenarios and scale up	ABSIG (KTN & Innovate UK) has scoped out the cost and potential for an open access facility. Decision as to how to progress is currently on hold whilst the budgetary implications of the Comprehensive Spending Review is assessed; Highlands and Islands Enterprise (HIE) is currently scoping the possibility of a Marine Bioprocessing Centre at Dunstaffnage: KTN & ABSIG are assisting in this consultation.	<ul style="list-style-type: none"> • KTN & ABSIG will continue to support HIE during the consultation and business plan development • Innovate UK will review the need and budget in 2016 • KTN & ABSIG will continue to promote Horizon 2020 programmes and encourage UK participation in such calls such as the 'Algae Integrated Biorefineries'.
	Mapping potential sites for sustainable cultivation	Some regional studies have been published (see Table 2).	Consolidation of all reports and studies in the UK; Examine potential impact of conflicting stakeholder interests.
	Encouraging IP generation	The Industrial Biotechnology Catalyst (IBC) funding scheme was launched in January 2013 aimed at driving the innovation pipeline from academia to commercial demo scale.	Ensure funding mechanisms are in place to support innovation in the bioeconomy space Creating a supportive entrepreneurial environment in universities.
	Expertise in: bioprospecting, strain development and metabolic engineering/synthetic biology toolkits	<p>The IBC scheme includes metabolic engineering and synthetic biology in the scope whilst bioprospecting and strain development is not.</p> <p>BBSRC-funded network on microalgae – PYCONET, aims to enhance collaboration between academia and industry and identifies strain development as a key focus of their activities.</p> <p>See also Table 2.</p>	Bioprospecting is an important consideration in business models. It is recommended that Innovate UK and BBSRC consider incorporating bioprospecting and strain development into the scope of funding calls plus ensure funding for synthetic biology toolkits for microalgae is maintained.

Identified enablers		Status	Proposed action
Financial	Security of funding for R&D, with increased accessibility for micro-SMEs, to attract and retain skilled personnel/entrepreneurs and accelerate commercialisation	The IBC, launched in 2013 is a strong commitment from government aimed at expediting the commercialisation process; Creation of BBSRC NIBB PHYCONET, offers a mechanism to enhance commercialisation and develop skills and training in early career scientists; The IBiolC offers funding for businesses to collaborate with one of their member universities, which includes SAMS – a centre with strong algal expertise; Cambridge University has opened an open access facility compatible for handling transgenic microalgae.	Ensure government continues to support bioeconomy innovation, including devolved governments.
	Successful examples of algal biotechnology applications leading to increased confidence and maturing supply chains	ABSIG has created case studies on commercialised algal products and services plus examples of ABSIG supported projects; ABSIG ran a workshop on microalgae aviation fuels which brought together the whole supply chain: Both Airbus and TUI Group are building pilot plants for aviation fuel.	Ensure positive case studies continue to be recognised and promoted. Encourage community to send any news to disseminate on the ABSIG website through biosciences@ktn-uk.org
	Attributing a direct value to bioremediation through financial incentives/penalties	Work in this area is not communicated widely.	More positive case studies need to emerge in this area.
Services	Closer interaction and knowledge transfer between academia and chemical & pharma industries to guide development of algal expression for platform chemicals and pharmaceutically interesting scaffold molecules	The Knowledge Transfer Network Ltd. continues to be the main contact and resource for business innovation in the UK through their extensive network of contacts. Connections can be business-to-business or business to academia. Whilst funding for the ABSIG ends in March 2016, support and resources will still exist in KTN to drive cohesion in the UK.	Ensure continual support for algae innovation under KTN activities and engagement with the Research Councils to ensure alignment & support mechanisms are in place.
	Algal bio-business incubator and clusters	No progress made on this.	Explore mechanisms and opportunities to develop this further.

	Identified enablers	Status	Proposed action
	Marketing/increasing visibility of UK expertise and products on the global stage: for environmental know-how, technologies and products	ABSIG and KTN Ltd., in collaboration with PHYCONET (a BBSRC NIBB) organised a Microalgae Mission to USA for ten UK academics & businesses; ABSIG has developed Case Studies to highlight UK expertise; ABSIG and KTN Ltd. ensure algal technologies are showcased in many of their organised events (e.g. Industrial Biotechnology Showcase 2015); KTN Ltd. has collaborated with Innovation Norway & Innovate UK to create a web-based UK-Norway Business Directory to aid collaboration & raise awareness of expertise (biodirectory.eu).	Encourage participation in Horizon 2020 and Newton Fund projects. Encourage businesses to add themselves to the Bioeconomy Business Directory biodirectory.eu Encourage membership of ABSIG and PHYCONET.
	Customer/public awareness and acceptance to increase demand	Social media is a powerful tool. The ABSIG Twitter account promotes algae news & new products; The EnAlgae project engages with the public on seaweed and its cultivation; The health benefits of seaweed is being driven by brands such as Mara Seaweed, where condiments are now widely sold in stores.	This activity must continue and businesses and academics should do more to promote their activities and/or products to the public. Trade, science and food fairs are great ways to engage with the public but also social media and marketing. Engaging in STEM activities can promote awareness in young students. KTN can assist in the promotion of new algae products.
Regulation	Providing clarity about regulatory context (macroalgae: marine licensing; microalgae: GMO regulation)	This issue is still a work in progress (but see Table 2).	
	Simplifying IP protection	Mechanisms exist to support simultaneous IP protection across several countries under one submission, see here ; The Intellectual Property Office & the Business & IP Centre are useful resources.	The funding landscape offered by Innovate UK will become clearer in 2016 and include more mechanisms for businesses to cover the cost for protecting their assets.

The key enablers identified in the Roadmap are detailed in Figure 2 whilst Table 2 describes some activities that have been happening in the UK to achieve those recommendations.

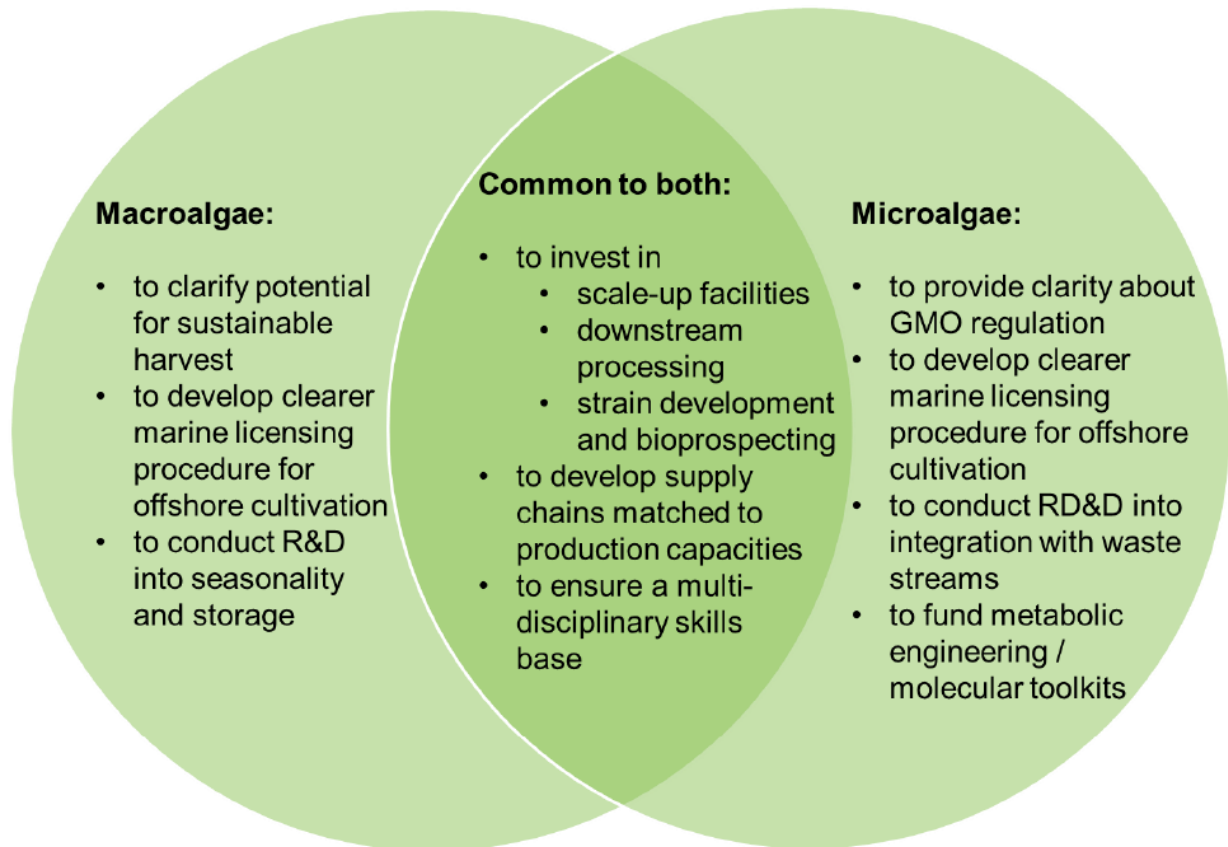


Figure 2. Recommendations from A UK Roadmap for Algal Technologies (Schlarb-Ridley & Parker, 2013) commissioned by the Algal Bioenergy Special Interest Group (ABSIG).

Table 2. Recommendations identified in the Roadmap with status update and proposed next steps.

Biomass	Recommendation	Status	Proposed next steps	Responsibility
Macroalgae	To clarify potential for sustainable harvest from wild & cultivated stocks.	The Crown Estate published a feasibility study on location mapping for a seaweed farm off East Anglian coast ^Ω 'Mapping the intertidal seaweed resources of the Outer Hebrides', Burrows et. al., 2010 'Prospects for the use of management for fuel in Ireland and the UK: An overview of marine management issues', Roberts & Upham (2012) [✱] .	Examine potential impact of conflicting stakeholder interests.	Research community
	To develop clearer marine licensing procedure for offshore cultivation (currently considered under same criteria as mussel farms).	Scottish Government has delivered a consultation on seaweed cultivation in Scotland [§] . A full report with recommendations is yet to be published. [¶] The Crown Estate is responsible for provision of marine licences except in Scotland where it is devolved to Marine Scotland.	Licencing needs clarity and consistent across devolved governments.	Crown Estate; Westminster and devolved governments.
	To conduct R&D into seasonality and storage.	A Google Scholar search on Seaweed Seasonality produced 738 results between 2014 & 2015; and 9 results relating to Seaweed Storage between 2011 & 2015 (19 Aug 2015); 'Ensiling of seaweed for a seaweed biofuel industry', Herrmann et. al., 2015 [∞] .	A key issue, and an area requiring further work, is the impact of different pre-treatments on the storage and subsequent viability of seaweeds.	Research community; early stage industry R&D supported by Innovate UK grant schemes.

Biomass	Recommendation	Status	Proposed next steps	Responsibility
Microalgae	To provide clarity about GMO regulation of culturing at large scale.	Microalgae strain engineering SME, Algenuity Ltd., has received a grant from Innovate UK to upscale the production of a microalgae-derived bio-pesticide (2015). This news arrives at the same as the Scottish Government bans the cultivation of GM crops in Scotland ^a ; The mixed message across the UK only enhances the uncertainty and reduces investor and consumer confidence.	More (strong) strain engineering projects submitted for funding and awarded; create positive case studies from such projects in order to enhance consumer and investor confidence.	Industry, academia, Research Council's, Innovate UK.
	To develop clearer marine licensing procedure for offshore cultivation.	This may be possible but too far off, the technology needs to be optimised.	Recognition as a research gap; require empirical data to inform clear licensing procedures.	Industry, academia, Research Council's, Innovate UK, Crown Estate, Devolved Governments.
	To conduct R&D into integration with waste streams	A particular strength in the UK. New SMEs emerging (e.g. Industrial Phycology Ltd., Phytofutures Ltd.)	Create supportive environment for SMEs working in this area and develop case studies to create positive investment climate and interest from water companies.	KTN can assist in the creation of case studies. BBSRC NIBB's offer mechanisms such as Business Interaction Vouchers and Proof of Concept grants and Innovate UK competitions also.
	To fund metabolic engineering/molecular toolkits	The Industrial Biotechnology Catalyst call included this topic, however ensuring a positive investment climate is important; PHYCONET (a BBSRC NIBB) offers funding in this area also.	Continued investment	Research Councils and Innovate UK.

Biomass	Recommendation	Status	Proposed next steps	Responsibility
Macroalgae & Microalgae	To invest in: (1) Scale up facilities (2) Downstream processing (3) Strain development & bioprospecting.	(1) Industry survey conducted 2014 by ABSIG on behalf of Innovate UK to establish need and what such a facility should like; (2) Incorporated into (1); (3) ABSIG SPARK Awards 2014; Industrial Biotechnology Catalyst (Strain development only); BBSRC various calls (prospecting); Publication by SAMS explores commercial potential of microalgae strains based on screening methodologies (Slocombe et al., 2015).	(1) Scoping out and costing of potential open access facility; Proposal to Business Innovation and Skills (BIS) for an open access facility; (2) Incorporated into (1); (3) Continued investment into identifying lead strains for commercial applications; develop a Top 100 list; Add bioprospecting to the scope of Innovate UK calls reflect the importance of linking academia with industry in context of bioactivity screening and development of robust business models.	Knowledge Transfer Network (KTN) & Innovate UK with support from NERC & BBSRC; (2) Incorporated into (1); (3) Mechanism: BBSRC & Innovate UK Support & knowledge transfer: KTN & PHYCONET.
	To develop supply chains matched to production capacities by joining up producers & processors; diversifying product range.	UK microalgae capability and molecule/functionality database created by ABSIG & PHYCONET*.	To ensure microalgae capability database is maintained and utilised as a resource for building supply chains and offering strategic direction meeting industry needs.	KTN/ABSIG & PHYCONET.

Biomass	Recommendation	Status	Proposed next steps	Responsibility
	To develop supply chains matched to production capacities by joining up producers & processors; diversifying product range, <i>Cont'd.</i>	<p>Some recent events aimed at informing, building supply chains, offering strategic direction:</p> <p>EU Projects Workshop, 'European Seaweed Production and Marketability', 13-14 May 2015, Oban; ABSIG & PHYCONET Workshop, 16 June 2015, Birmingham '<i>Commercialising Microalgae: Determining industry needs</i>';</p> <p>ABSIG Workshop, 24 November 2015, Birmingham '<i>Algae as a tool in ecosystem services: Microalgae to aviation biofuels</i>'</p> <p>Formation of the Scottish Seaweed Association 2014;</p> <p>Mara Seaweed and the Cornish Seaweed Co. have built supply chains to enable commercialisation of seaweed products;</p> <p>Creation of 13 BBSRC Networks in IB & Bioenergy. Of relevance to algal supply chains: Plants to Products, PHYCONET, IBCarb.</p>	Ensure business support mechanisms continue such as the Knowledge Transfer Network (managers of the ABSIG) to assist the networking process and business development.	Innovate UK, Research Councils.
	To ensure a multi-disciplinary skills base.	<p>New Postgraduate courses:</p> <p>Algae Biotechnology (UHI)</p> <p>Industrial Biotechnology Innovation Centre (IBiolC) MSc & PhD Courses.</p> <p>RC Postgraduate schemes:</p> <p>BBSRC Industrial CASE PhD Studentships.</p> <p>EPSRC Industrial CASE PhD Studentships.</p>	Ensure undergraduate and postgraduate courses are industry relevant.	Universities.

Biomass	Recommendation	Status	Proposed next steps	Responsibility
	To ensure a multi-disciplinary skills base, <i>Cont'd.</i>	NERC Industrial CASE PhD Studentships. ESRC Doctoral Training Centres. Career Development Courses: SAMS (e.g. Algaculture for biotechnology, October 2015); Marine Biological Association offers regular courses (taxonomy of seaweeds to molecular techniques)		
<p>Slocombe et al., Unlocking nature's treasure-chest: screening for oleaginous algae. Nature Scientific Reports 5, 9844 ^Ωhttp://www.thecrownestate.co.uk/media/389748/ei-potential-locations-for-macro-algae-farming-off-the-coast-of-east-anglia.pdf [¥]Marine Policy 36, 1047-1053 [§]http://www.gov.scot/Publications/2014/11/5316/downloads [¶]http://www.thecrownestate.co.uk/coastal/what-we-do/ [∞]Bioresource Technology, 196, 301-313 ^αhttp://news.scotland.gov.uk/News/GM-crop-ban-1bd2.aspx [*]https://connect.innovateuk.org/web/algae-biotechnology-special-interest-group/overview</p>				

3. Conclusions

Whilst progress has been made since the publication of the Roadmap in 2013 (see Table 2), there remains a significant amount of work to do to create a robust, supported, growing and sustainable algal industry in the UK. The enablers and recommendations identified in the Roadmap remain pertinent and hence efforts need to be maintained to address them.

Supporting an algae-based future in the UK

The budget from NERC and Innovate UK to finance specific algae activities (e.g. events, missions and SPARK Awards) will not be continued beyond March 2016. KTN will continue to facilitate commercialisation and innovation in algae technologies in partnership with Innovate UK and Business, Innovation and Skills. The team can still advice on funding, make connections, critique funding applications and participate in strategic activities, including supporting the actions identified in the Roadmap.

Funding algal innovation

Funding for projects to support innovation must continue and include mechanisms to enable businesses to develop pilot and commercial plants. Based on communication the ABSIG and Knowledge Transfer Network receive, accessing finance to scale up processes and cultivation is a continual issue for businesses. The positive outcome of the 2015 Comprehensive Spending Review announced by the Chancellor could mean that provisions will be in place to enable businesses to achieve this ambition. The funding landscape will become clearer for businesses and academia alike through 2016.

Aside from UK-wide grant support, the devolved nations also offer their own schemes and can include funds for capital investment (e.g. [Scottish Enterprise](#)). Regional schemes exist also (e.g. [Capital Grant Scheme](#), Biorenewables Development Centre and [IBiolC](#)) aimed at creating regional growth.

Highlighting UK success

Case studies are slowly emerging and the ABSIG and KTN are keen to ensure this continues. The team would like to ask the algae community to **share their success stories**, whether commercial or research, on the ABSIG website. This news can then be circulated through a monthly newsletter and social media. To find out how to do this, go to the [website](#).