Climate: the case for marine bioenergy in Europe and The Crown Estate's response in the UK

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Key Message

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- Macroalgae biofuels and other products will be big!

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Role of The Crown Estate in the UK

- The Crown Estate is a public body
- Manages ~50% UK foreshore and almost all seabed out to 12nm
- Energy and mineral rights out to 200nm
- Operates under The Crown Estate Act 1961
- <u>Duty to maintain and enhance the value of the estate and return from it</u>
- Due regard for principles of good management
- Stewardship is a Core value
- The Crown Estate is not in any sense a Regulator for activities on its estate

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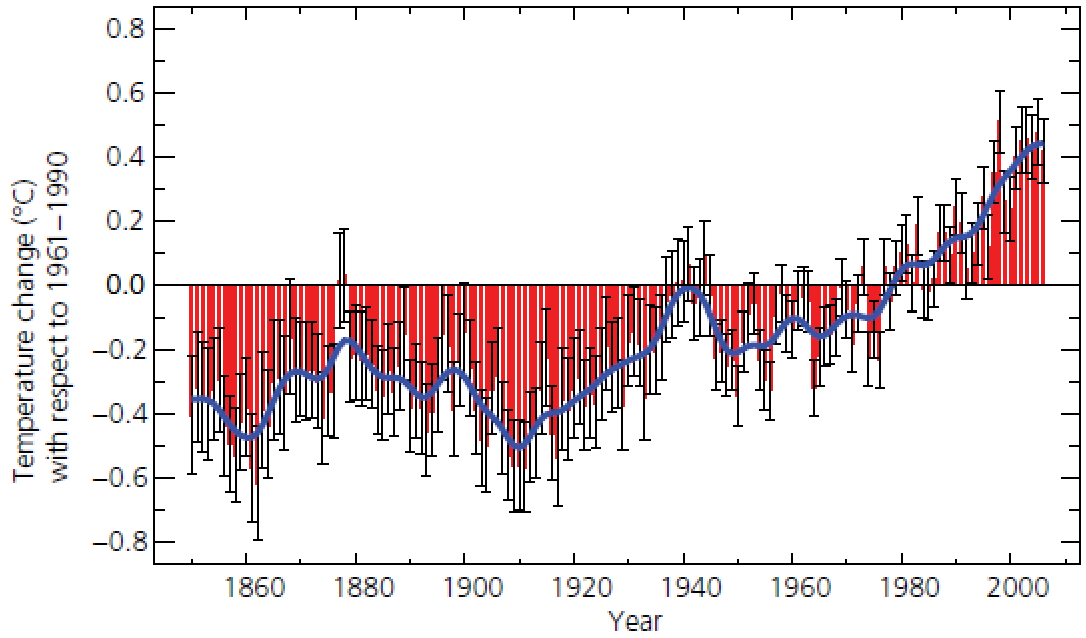
Annual average global mean near-surface temperature



(UK CP09 'Trends')

- Temperature increased ~0.8˚C since ~1850
- Trend over last 25 years much greater, ~0.2˚C per decade
- "Warming unequivocal", IPCC 2007
- "Very likely (>90% prob) that human greenhouse gas emissions caused most of temp rise since ~1950." UKCP09
- Emissions 'in the system' will result in further ~0.6˚C

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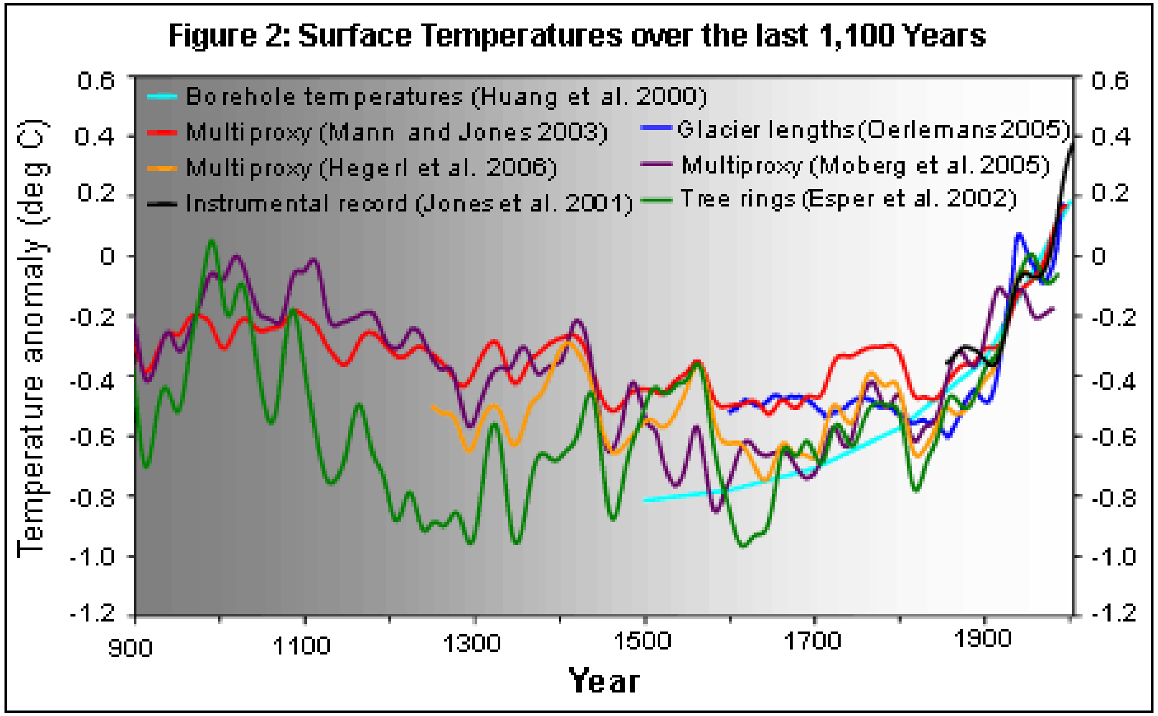
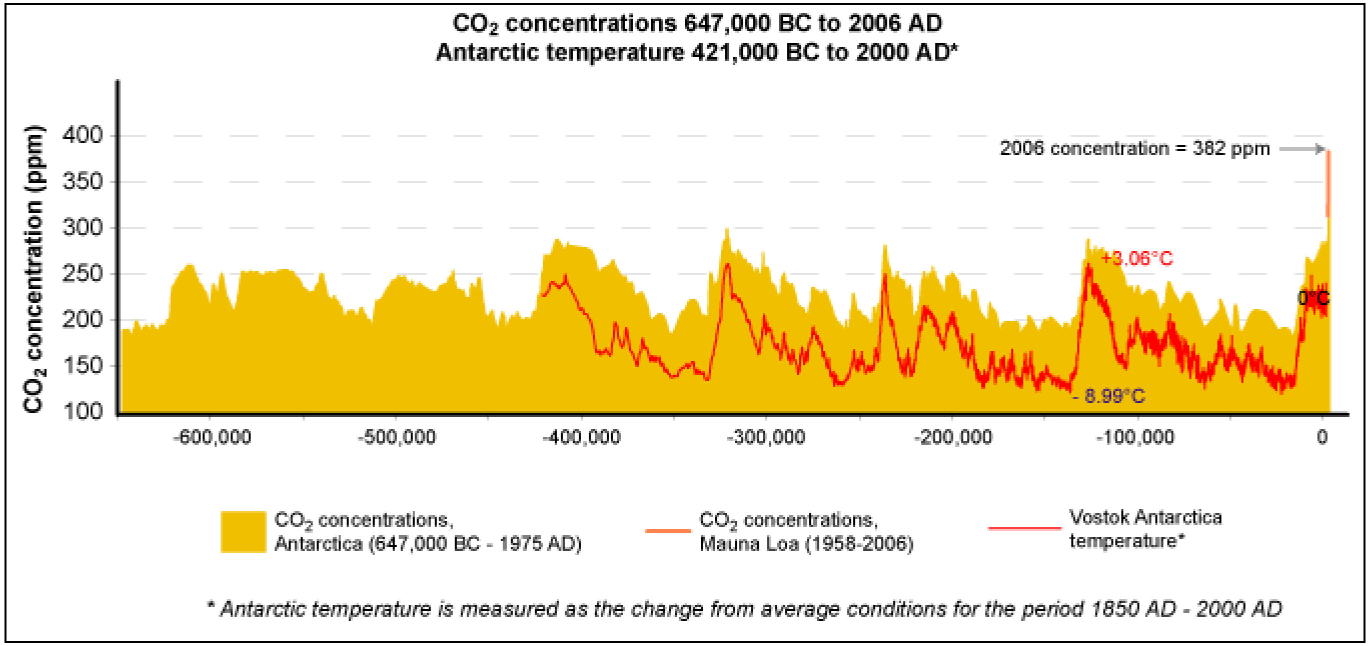
Changes in surface temperature, various measures



- Uncertainty increases to left (shading)
- US EPA

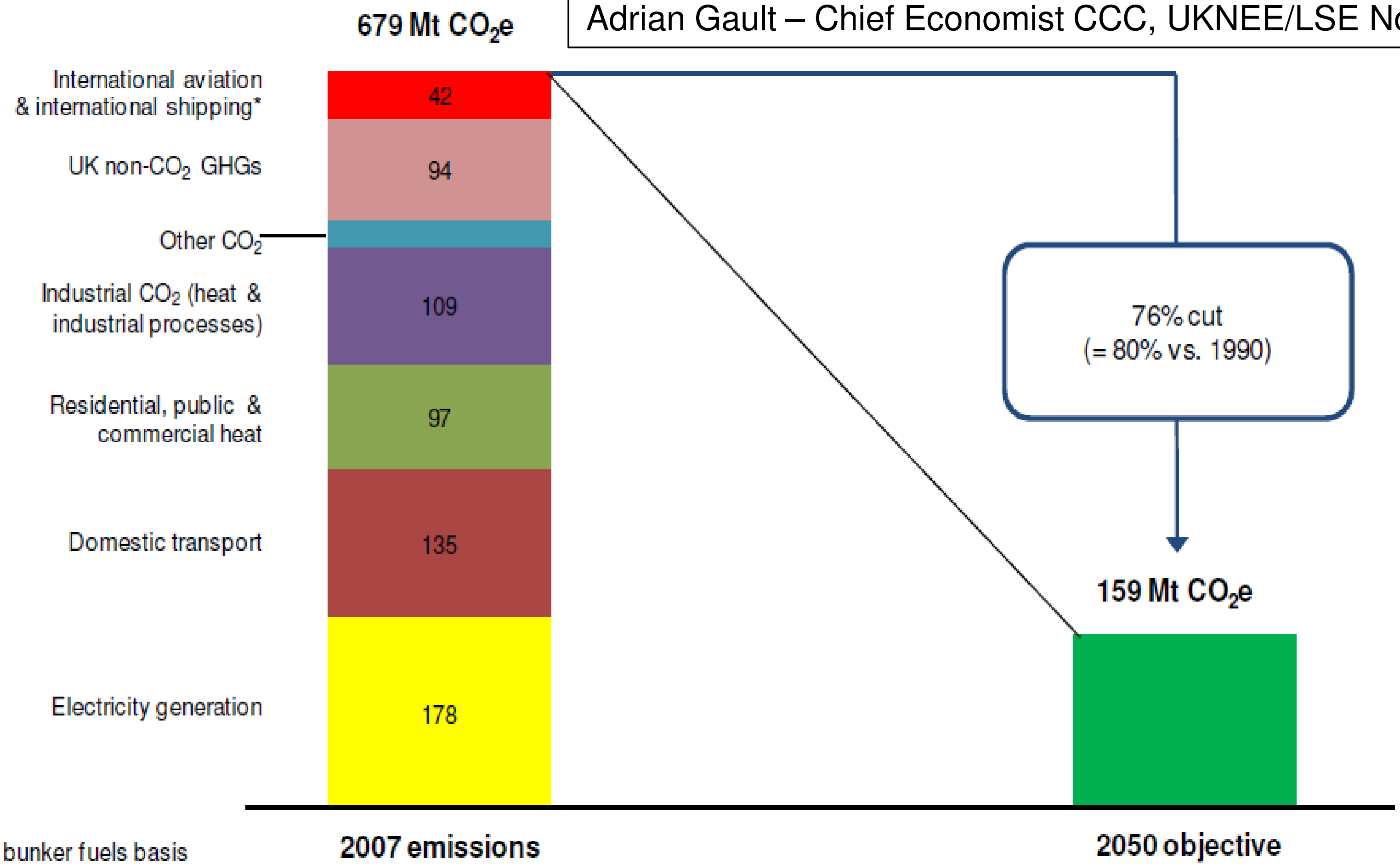
Changes in atmospheric CO_2 and Antarctic temperature



US EPA

(i) The budgets put the UK on a path to reducing emissions by 80% by 2050

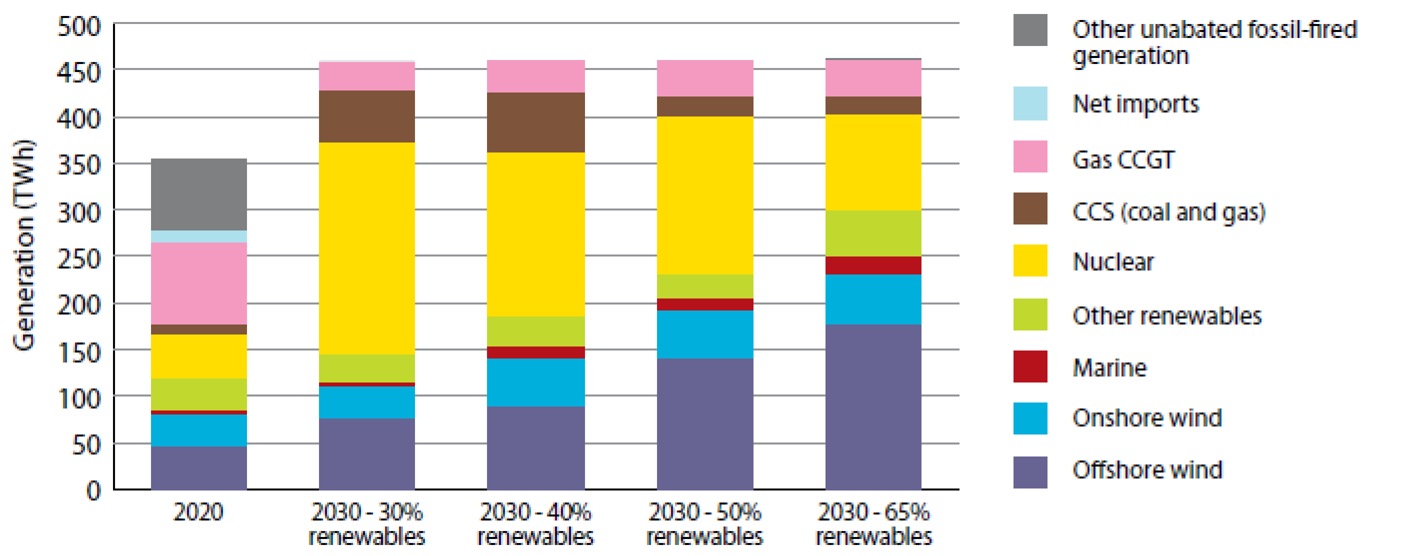
Adrian Gault – Chief Economist CCC, UKNEE/LSE Nov'09



* bunker fuels basis

Latest UK carbon budget scenarios – CCC May 2011

Figure 3: Renewable generation scenarios to 2030

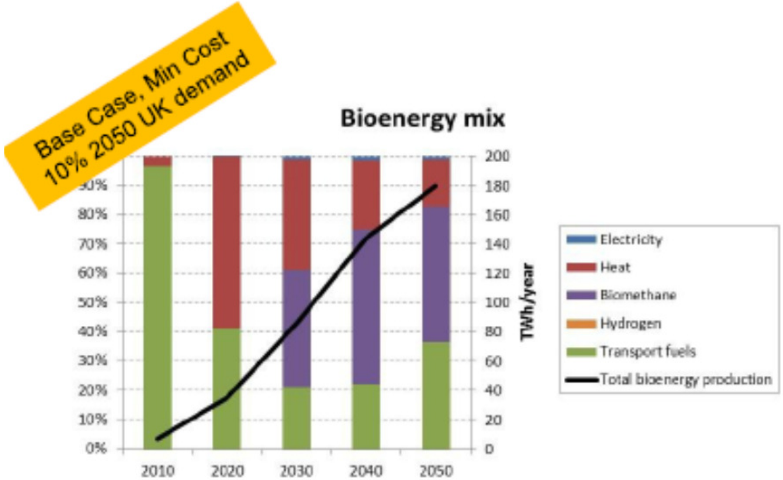


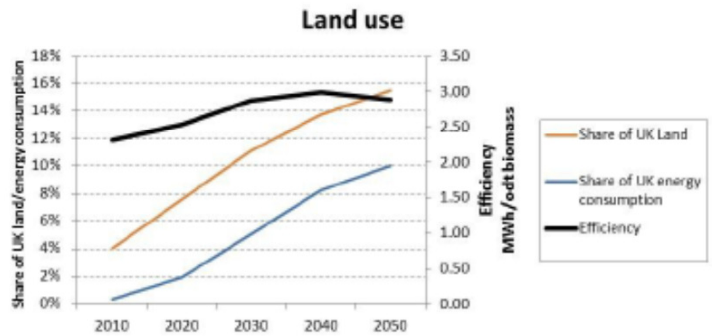
Source: CCC calculations, based on modelling by Pöyry Management Consulting.

Note(s): All 2030 scenarios achieve a comparable level of emissions intensity (around 50 g/kWh) and security of supply.
Includes losses, excludes generator own-use and autogeneration. Other renewables include hydro, biomass (including anaerobic digestion), geothermal and solar PV.

… but 10% of UK energy demand in 2050 is a realistic target

- A share between 10% and 20% would involve using up to 15% to 25% of UK land
- And with enough high grade land set aside for wheat production for human consumption





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Sub-area	Technology	Value in meeting emissions targets at low cost £bn	Value in business creation £bn	Innovation Priorities
New Energy Feedstock	Woody/Grassy Crops	4.7 (2.4 – 13.5)	2.6 (0.7 - 3.8)	▪ Crop cost reductions and improved sustainability through yield increases and capacity to plant on marginal land in a way that does not compromise the delivery of important ecosystem services ▪ Development of crops that are suited to farmers' needs (short maturity times, ease of grubbing up)
	Oily Crops	5.6 (0.0 - 24.3)	0.3 (0.0 - 0.4)	
	Microalgae	1.0 (0.0 – 2.9)	0.4 (0.0 - 3.4)	▪ Cost reductions through increases in yield and harvestable energy content ▪ Risk reduction through development of species robust to production conditions
	Macroalgae	0.3 (0.0 - 3.4)	0.5 (0.0 - 1.1)	▪ Reduction of macroalgae cultivation and conversion costs, improving yields, and proving economical production at scale in UK waters ▪ Improved assessment of environmental impacts and costs
Biomethane	Anaerobic Digestion	2.6 (2.0 - 4.9)	1.1 (0.8 - 1.2)	▪ Development of improved pre-treatment, digestion and gas upgrading components, capable of taking mixed feedstocks
	BioSNG	0.9 (0.0 - 4.8)	1.0 (0.0 - 1.2)	▪ Large scale demonstration of a fully integrated plant ▪ Improved catalysts and syngas clean-up to enable cheaper, more reliable production at a smaller scale
Bioheat	Small Scale	1.7 (0.1 - 3.1)	0.9 (0.4 - 1.2)	▪ Incremental increases in system efficiencies ▪ improved installation techniques and control mechanisms
	Large Scale Heat	0.2 (0.0 - 0.9)	3.6 (1.9 - 6.7)	
Biopower	Combustion	3.0 (1.7 - 4.7)	4.6 (3.1 - 5.7)	▪ Development of advanced boilers and operation systems that are robust to a variety of feedstocks ▪ Establish combustion facilities that are compatible with CCS
	Gasification	1.7 (0.0 - 5.6)	0.6 (0.0 - 1.1)	▪ Large scale demonstration activities, pursuing efficiency increases (especially through modification of high efficiency gas turbines for an H_2–rich fuel) and reliable, durable production, using sustainable feedstocks ▪ Compatibility with CCS
Advanced Biofuels	Gasification Routes	7.9 (0.0 - 67.8)	1.1 (0.2 - 3.6)	▪ Large scale demonstration of a fully integrated plant ▪ Improved catalysts and syngas clean-up to enable cheaper, more reliable production at a smaller scale
	Pyrolysis Derived Fuel	3.9 (0.0 - 65.6)	0.7 (0.0 - 4.8)	▪ Cost reductions through development of co-processing capability in conventional oil refineries ▪ Development of robust fast pyrolysis techniques, capable of utilising mixed feedstock
	Novel Fuels	2.9 (0.0 - 68.1)	0.4 (0.0 - 3.1)	▪ *For biological systems:* Cost reductions and reliability improvements through bacteria and yeast optimisation ▪ *For chemical routes:* Cost reductions and reliability improvements through catalyst optimisation
	Lignocellulosic Ethanol	3.7 (0.0 - 19.5)	0.5 (0.3 - 1.4)	▪ Development and demonstration of the pre-treatment stage to enable improved use of lignocellulosic material in the fermentation process, and maximise co-product revenues or use on-site ▪ Optimisation of hydrolysis and fermentation techniques (especially for butanol fermentation)
	Lignocellulosic Butanol	2.3 (0.0 - 21.8)	0.6 (0.3 - 2.7)	

Figure 1: Bioenergy TINA summary

Benefit of UK public sector activity/investment: Low | Medium | High

Bioenergy: benefit of public sector investment in UK

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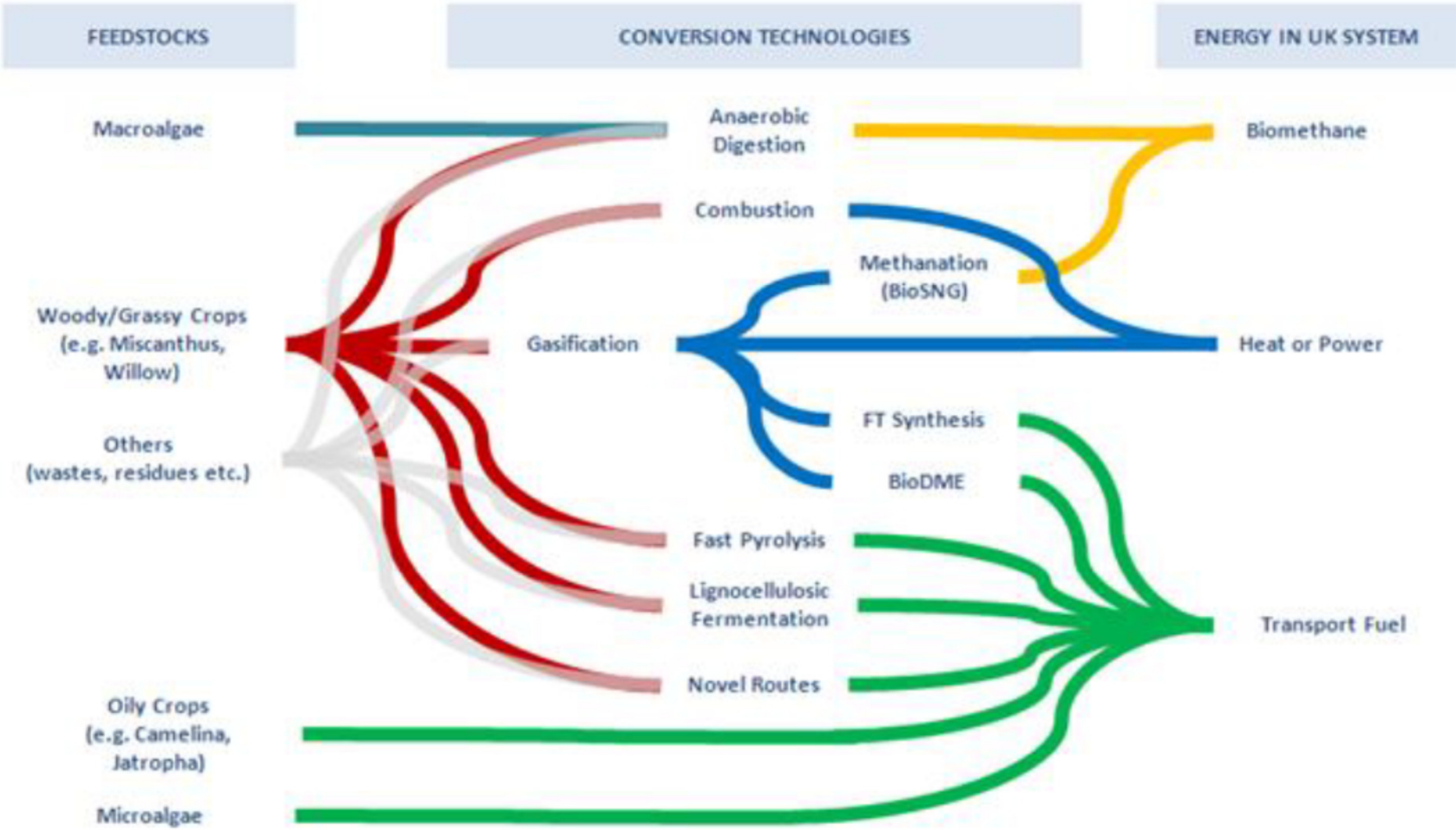
Bioenergy Flow Chart



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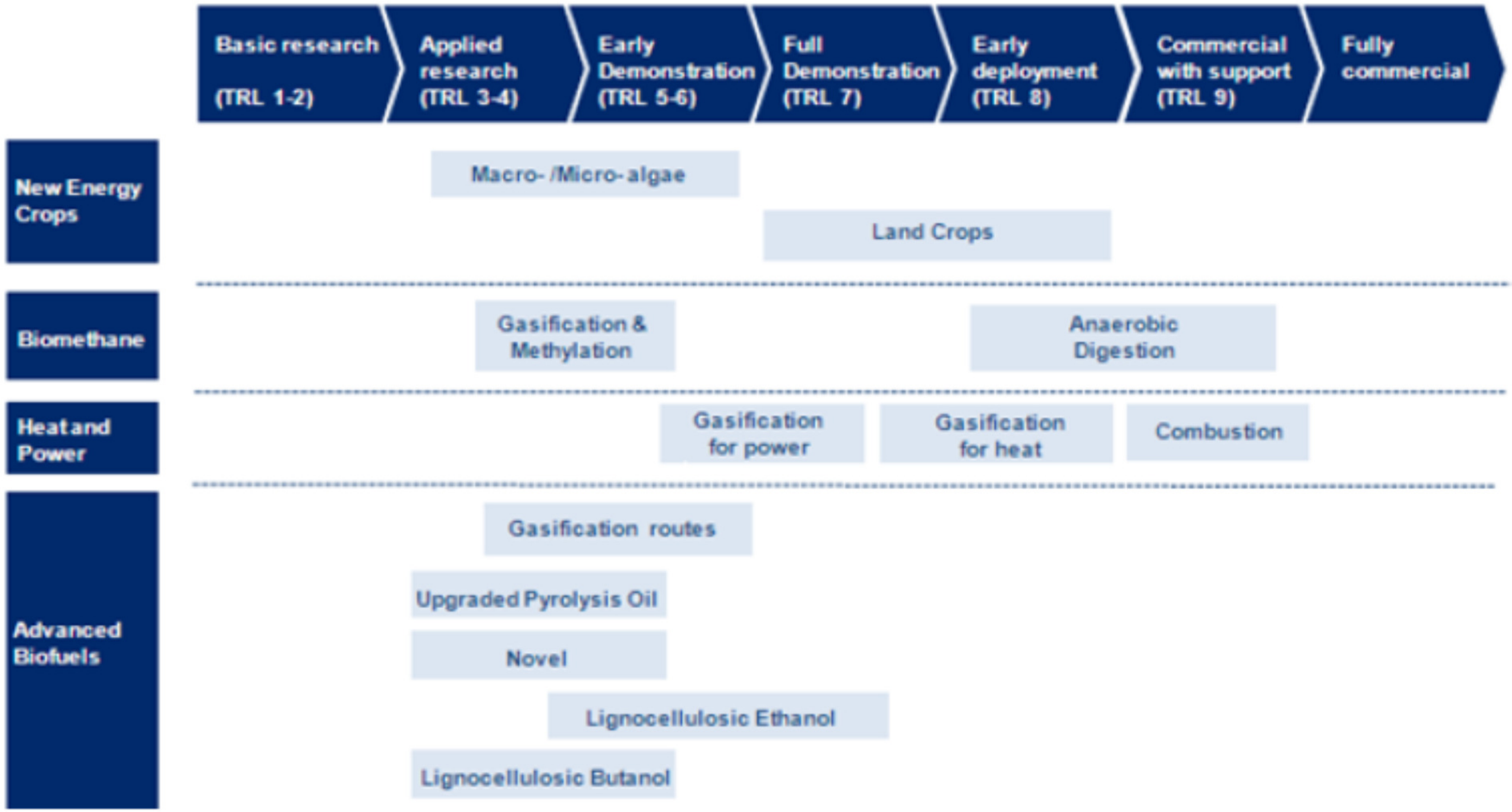
Bioenergy: Technology readiness levels



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Vision

- Marine Biomass is the newest (9th) business sector for the Marine Estate
- Principal interest is leasing the seabed for the benefit of the UK taxpayer
- Primary interest is farming of macro-algae
- Need to think on large scale & long-term
- Focus on 'enabling' hence support for background studies to de-risk potential business and reduce uncertainties

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Macro-algae Bioenergy

- Large-scale use of natural stocks is unsustainable
- Farming needs to be focused on an energy industry, rather than diversification of aquaculture
- Total potential for UK significant
- Does not use agricultural land or freshwater
- Cascade of products as well as energy

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Building a business

- Is there demand for the product(s)?
- Can the product(s) be produced at a cost such that it is possible to make a profit?
- What are the risks to the business
- What barriers need to be overcome?
- Is the business sustainable in the longterm?
- When can we start?

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Initial 3 species for consideration

Saccharina latissima

Laminaria digitata

Laminaria hyperborea

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What we appear to know

- Productivity ~20 tonnes dry weight/ha/annum*
- With nutrient addition may get ~50t/ha/annum*
- Potential area for UK? 15,000km^2 ?
- ~30mt dry biomass pa → ~700 Petajoules pa
- 2011 UK demand 212mt oil equivalent ~8,876 PJ

*Hans Reith, Netherlands Energy Research Centre

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Goals for 2011/13

- UK understanding - beyond academia:

- Products & processes (Just what would you do with 1m tonnes of wet seaweed to make money?)
- How will it be grown? (Not like mussels)
- Where is the energy balance? (How green?)
- What are the likely environmental consequences?

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Products & Processes (i)

- Lack of attention on this issue in prior studies
- CPI study for The Crown Estate guides product choice
- Includes analyses of market resilience for products
- Indicates maximum production costs for farmed algae

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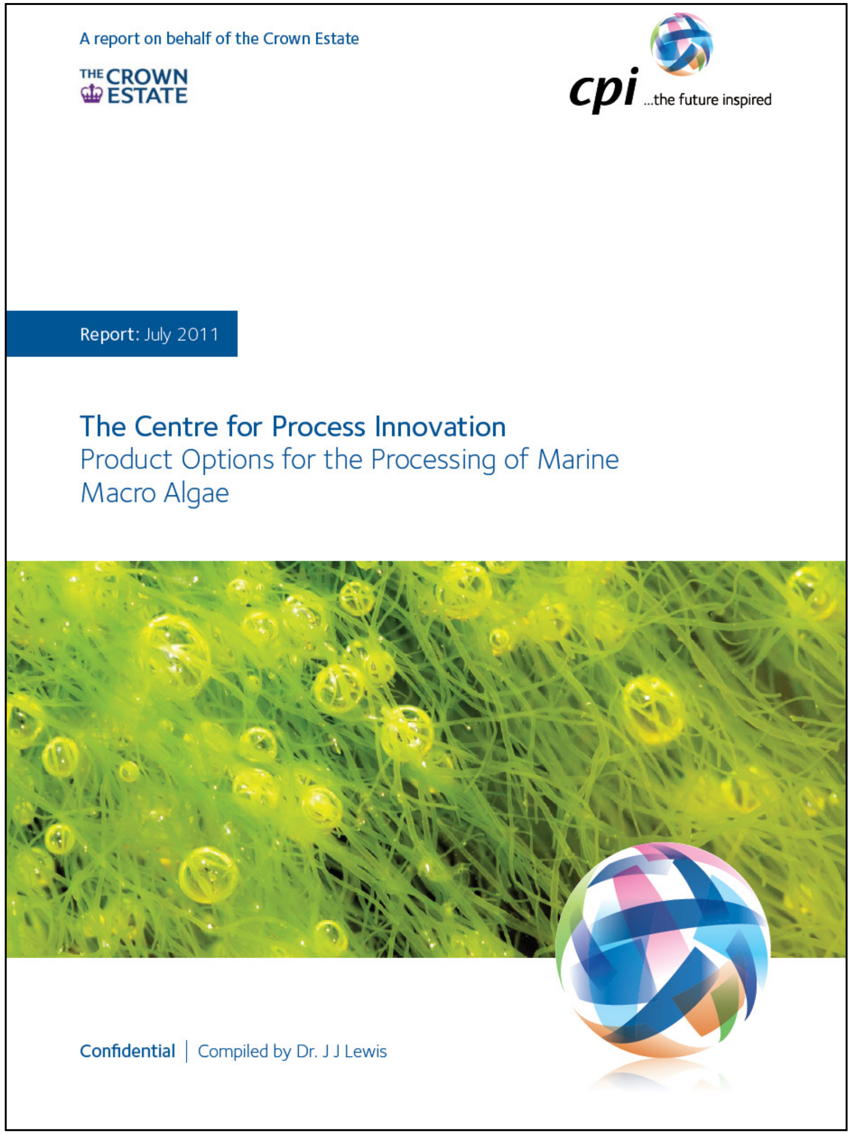
Product & Processes (ii)


A report on behalf of the Crown Estate

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cpi ...the future inspired

Report: July 2011

The Centre for Process Innovation
Product Options for the Processing of Marine Macro Algae

Confidential | Compiled by Dr. J J Lewis

- Report on website
- Alginates, Mannitol, Laminarin, Fucoidan, Bioactives not business opp.
- Ethanol needs further work + patent issues
- Butanol should not be pursued at present
- AD with mixed stream realistic proposition
- http://www.thecrownestate.co.uk/media/271433/products_from_marine_macro-algae_2011.pdf

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Products & Processes (iii)

- Seasonality of macro-algae is significant issue
- Storage of wet macro-algae is an issue
- Seasonal variation in composition needs consideration
- Renewable subsidies critical in early stages
- Easy to make case totally uneconomic

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How will macro-algae be grown?

- Not ropes like mussels – labour is too expensive
- Need analogue of mowing a lawn
- Farms will be large, >1,000ha, possibly 10,000ha
- Several species grown at any one time
- Not all species harvested every year
- No year in which total crop harvested
- Different species will have different life-spans before replacement, up to 20 years.
- Harvesting and transport has to be cheap
- Storage of cut crop is a problem

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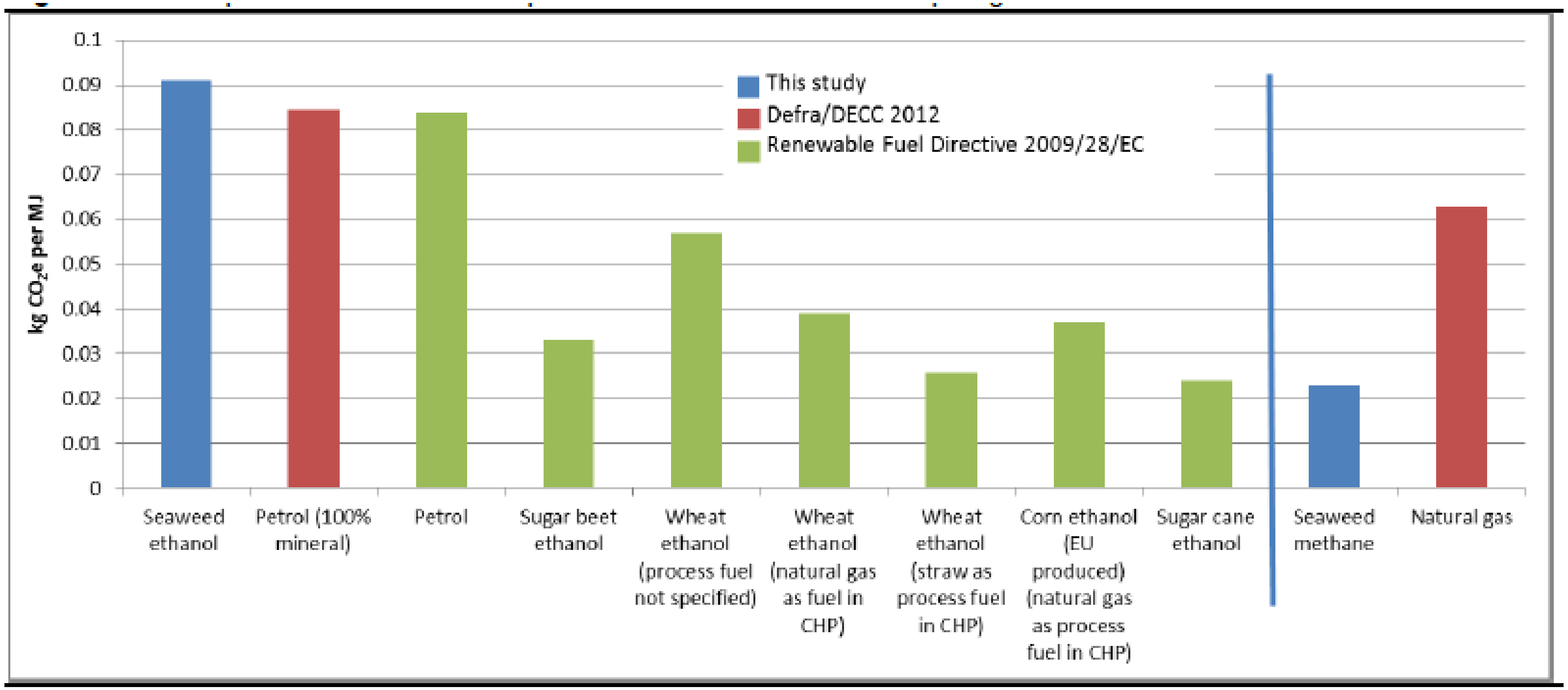
Macro-algae Biomass – Energy Balance



- ERM Carbon footprint report on The Crown Estate website
- Methane is obvious product
- Meets all future EU GHG reduction requirements
- Ready market for worldwide commodity

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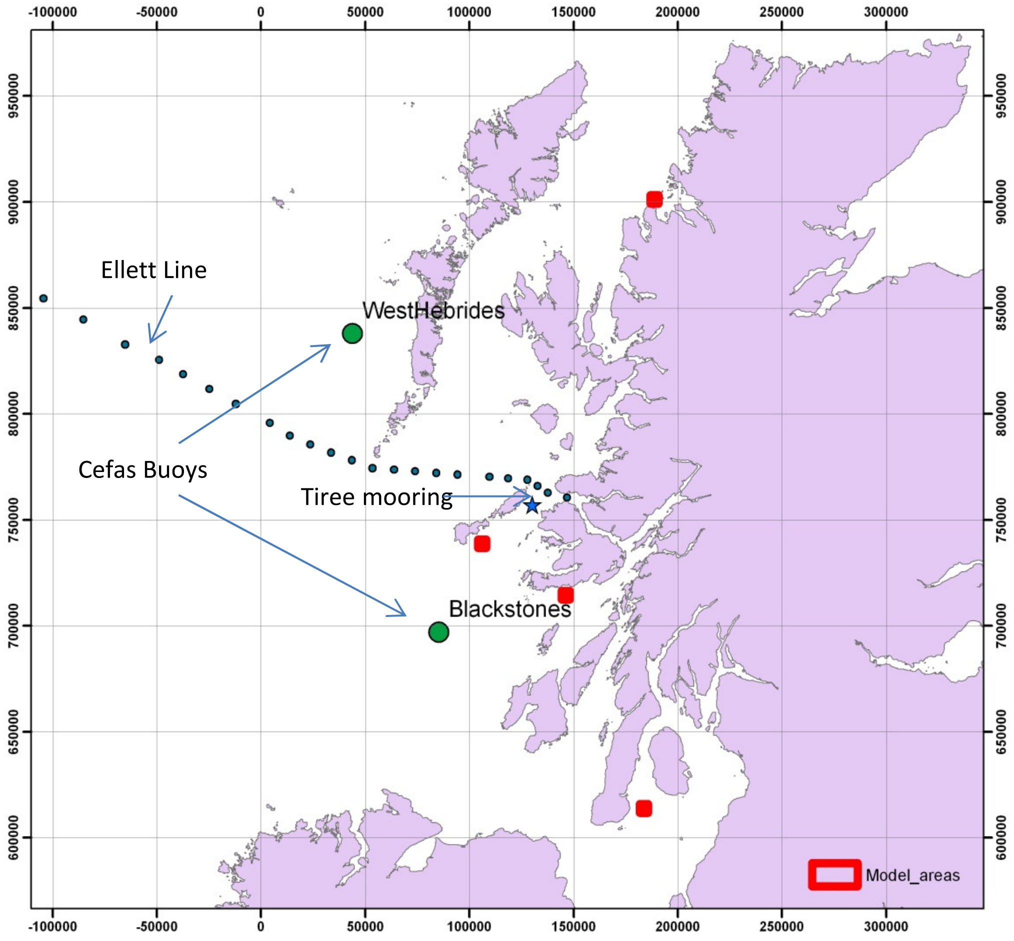
Likely environmental consequences?

- Initial Ecosystem services modelling study
- Cefas as contractor
- 4 model areas off west coast of Scotland
- At least 3 species of brown algae
- Initial results show modest impacts over 10km
- Further work to refine impacts and significance



Note: these are not potential lease areas

Ecosystem Model Areas

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Seaweed for Biofuels

Commercial Macro-algae Production Pilot

Trondheim 25-26 September 2012

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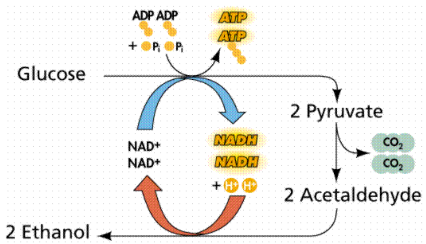
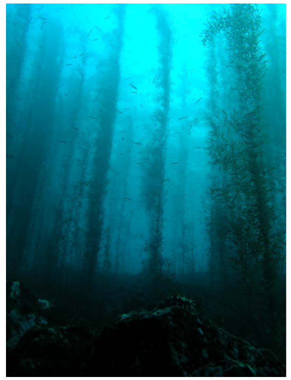
The Pilot – Concept & Approach

Commercial products The processes & production options Cultivation – species, scale and logistics





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Species, Scale & Logistics

= The Macro-algae Supply Chain Project (MSCP)

Steering Group comprising:

1. The Crown Estate – funding and wider pilot studies
2. Seawork International Ltd – mooring and system design
3. Viking Fish Farms Ltd – marine hatchery expertise, esp.seaweeds
4. Muckairn Mussels Ltd – shellfish and seaweed farming
5. W&J Knox Ltd – net and rope substrate manufacturer

Focus on practical and commercial viability

Exploring the potential of two production concepts

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Current UK Production

Current UK cultivation – suspended long-lines & droppers

Producer developments include

- continuous line ('New Zealand' system) for continuous stripping
- with horizontal line deployment?

Seeding of cultivation ropes via hatchery-seeded twine, by hand, or in situ seeding via wild spawning

Harvest – in situ manual stripping

All inshore

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Future production concepts 1

Production & harvest with minimal -

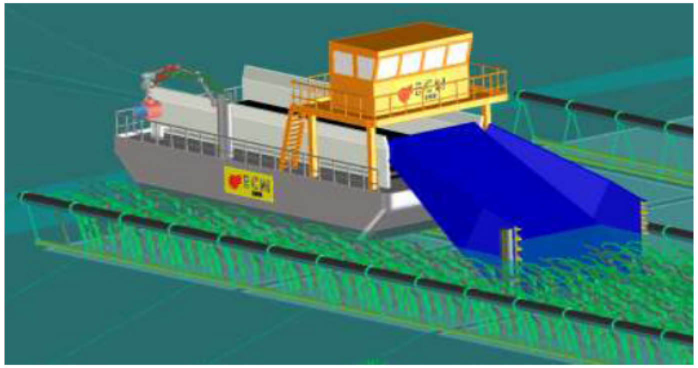
- in situ substrate handling
- immediate re-seeding requirement

essentially cropping/coppicing with most operations on site

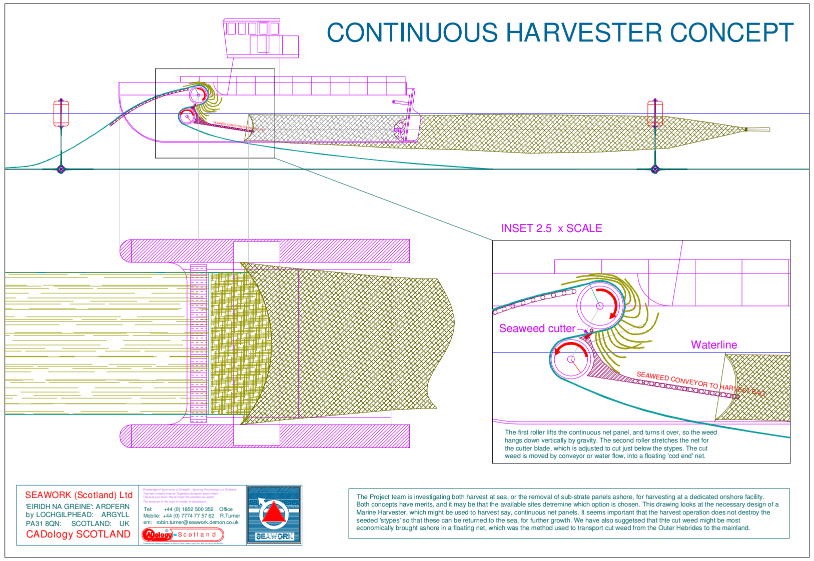
(~ natural stock harvesting)

Issues include;

- accessibility – of location & crop
- cultivation system mooring requirements
- inter-crop fouling
- inshore vs offshore potential?



Courtesy: Hans Reith, Netherlands Energy Research Centre



Courtesy: Seawork Intl Ltd

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Future production concepts 2

Production & harvest with

- retrieval of substrate for cropping
- re-seeding with re-deployment

essentially planting out & retrieving in conjunction with shore-side harvesting (and processing) facility, or ‘klondiker’ vessel

Single mooring system designs provide for offshore location/accessibility

Issues include:

- (re-)seeding requirements
- cultivation efficiencies vs costs
- security and scale required

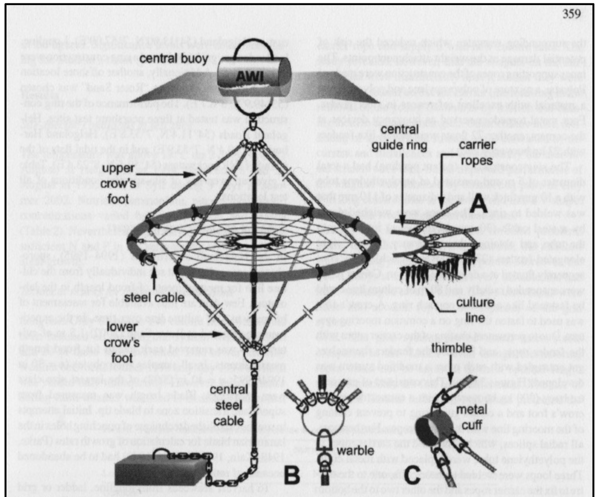
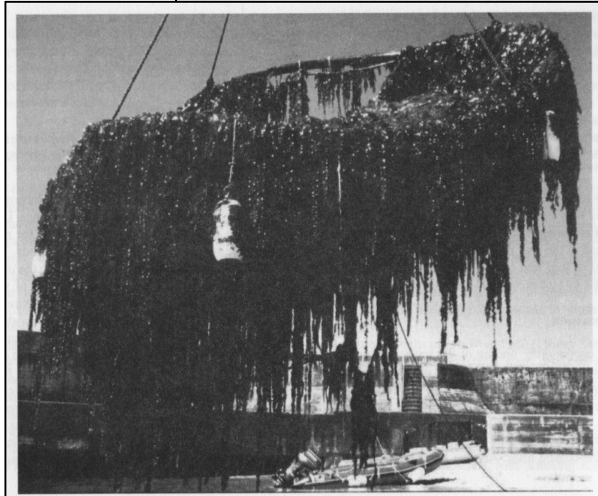


Figure 3. The successful ring design for the culture of *Laminaria* at offshore locations. The major elements of the system design are magnified: (A) central guide ring with attached carrier rope and culture line, (B) the transition between central steel cable of the mooring and that of the lower crow's foot, (C) metal cuffs, to which the crow's feet and the carrier ropes are attached.



Buck, H B & Bucholz, C M
Journal of Applied Phycology 16: 355-368, 2004

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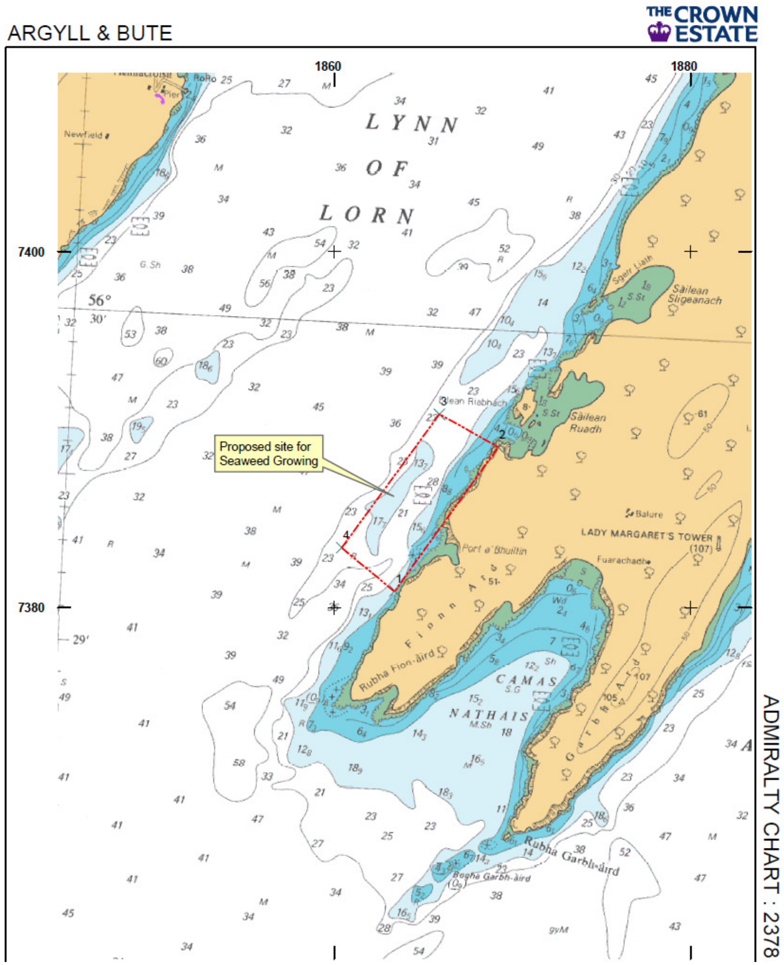
MSCP – Status

- 35ha site in Lynn of Lorne, Argyll
- Selected for location but also access
- Surveyed and Marine Licence granted.
- Initial deployment aimed for autumn/winter 2012
- Cultivation system designs in place
- Seeding trials underway



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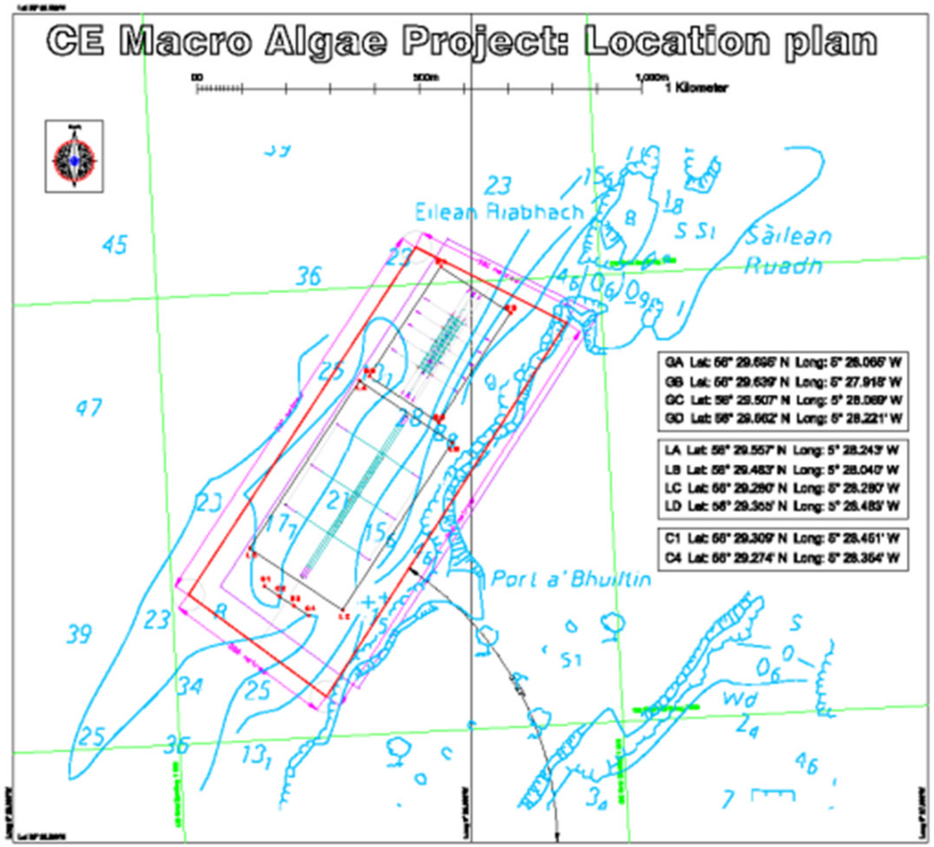
MSCP Aims

Investigate logistics of

- Systems and substrate
- Seeding
- Production performance
- Harvest

of seaweeds (kelps) with the two concepts described, against current method controls.



The 'scale-ability' of the systems and processes investigated.

The commercial viability – at scale.

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Conclusions

- Marine Macro-algal Biomass can make a significant contribution to energy security for UK
- Potential cascade of products as well as energy
- Economics of products and processes is key
- Much more attractive than terrestrial biomass
- Does not need CCS to achieve GHG reduction
- Planned pilot an important next step
- Overall, marine biomass could be ‘big’ – equivalent of many GW continuous

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Thank You

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