WP6: Sustainability Assessment

Progress Meeting 5th July 2017

AU, AVT, ECN, Eurida, SAMS, SIOEN, ERM

Scope of WP6

The sustainability assessment is a multi-criteria appraisal with the aim of **evaluating the impacts of seaweed-derived transport fuels with respect to the environment and society, their technical and economic viability and health, safety and risk aspects** of seaweed biofuel production systems.

The overall objective is three-fold:

- Assess the overall sustainability of biofuels from seaweed, identifying where in the supply chain the main impacts occur;
- Benchmark the sustainability of different value chains for biofuel production within the MacroFuels concept; and
- Benchmark the sustainability of MacroFuels against equivalent conventional, fossil-based, fuels and currently available biofuels.

Scope and timeline of WP6

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6.1 Scoping and boundary setting (ERM, M6-M12)

6.2 Techno-**economic** assessment, safety and health risk assessment (ECN, M12-M28)

6.3 **Social** assessment: Regional and social aspects (Eurida, M12-M42)

6.4 **Environmental** assessment: Life cycle assessment (ERM, M24-M36)

6.5 Environmental and business risk assessment (AU, SAMS, AVT, SIOEN, M12-M40)

6.6 Sustainability assessment (ERM, M36-M48)

Scope of WP6

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Scenario	Description
Main scenarios	
Ethanol & co-products	Production of ethanol and the co-products of proteins and nutrients.
ABE & co-products	Production of butanol and the co-products of protein, nutrients, and hydrogen.
Furanics & co-products	Production of furanics and the co-products of mannitol and proteins.

Additional scenarios evaluating variations / variabilities

WP6.2: Techno-economic evaluation

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Jan Wilco Dijkstra, Dick Meyer, Wouter Huijgen, Jaap van Hal (ECN)

Overview of activities

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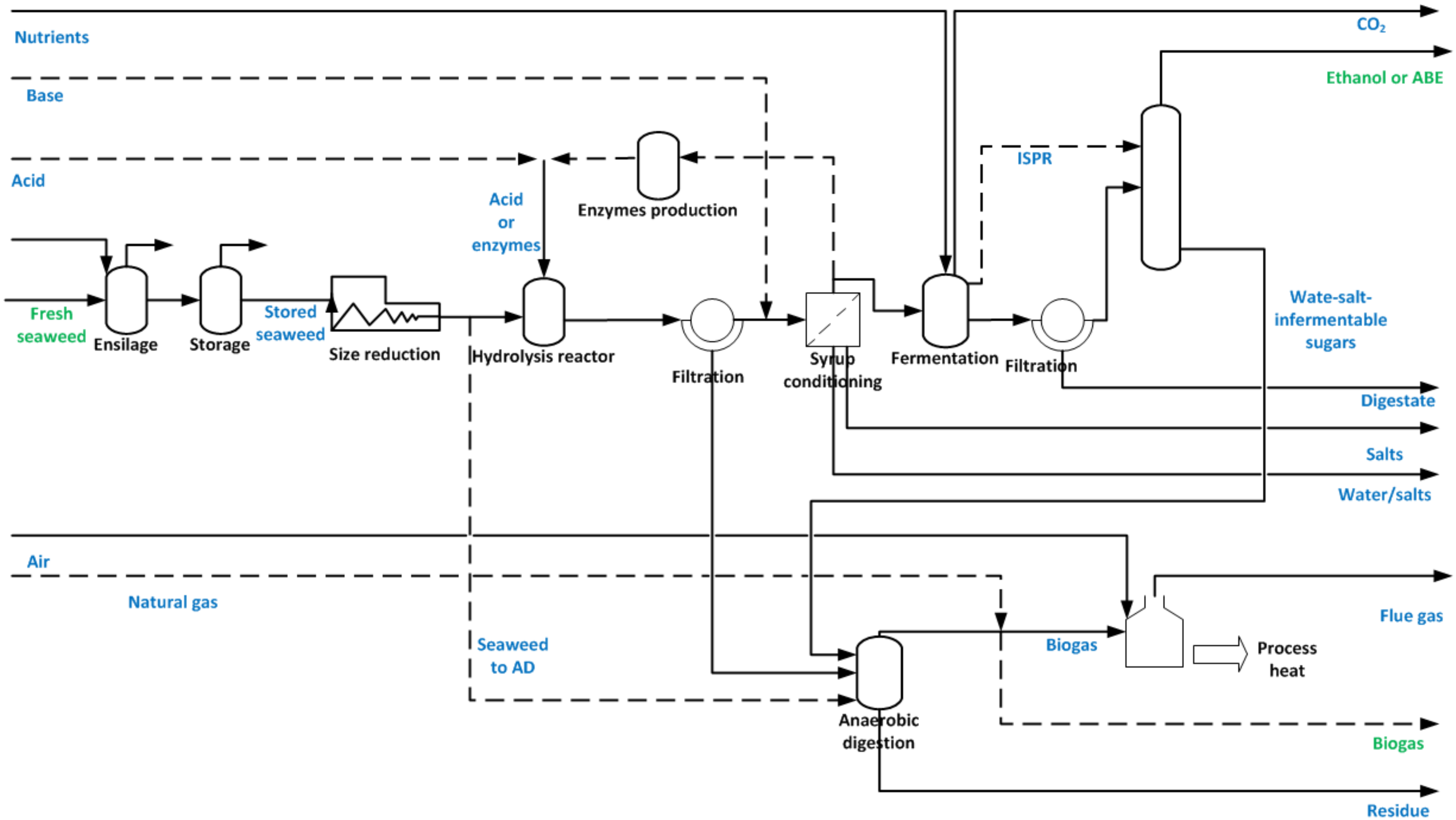
- Grow-out unit concept choice:
  - Functional diagram
  - Methodology update

- Setting up first case:
  - Saccharina lat. to EtOH case, preparations for ABE
  - Develop modelling approach
  - Translate seaweed analysis into model components
  - Start with model development and implementation

Seaweed biorefinery schematic



Progress storage & processing

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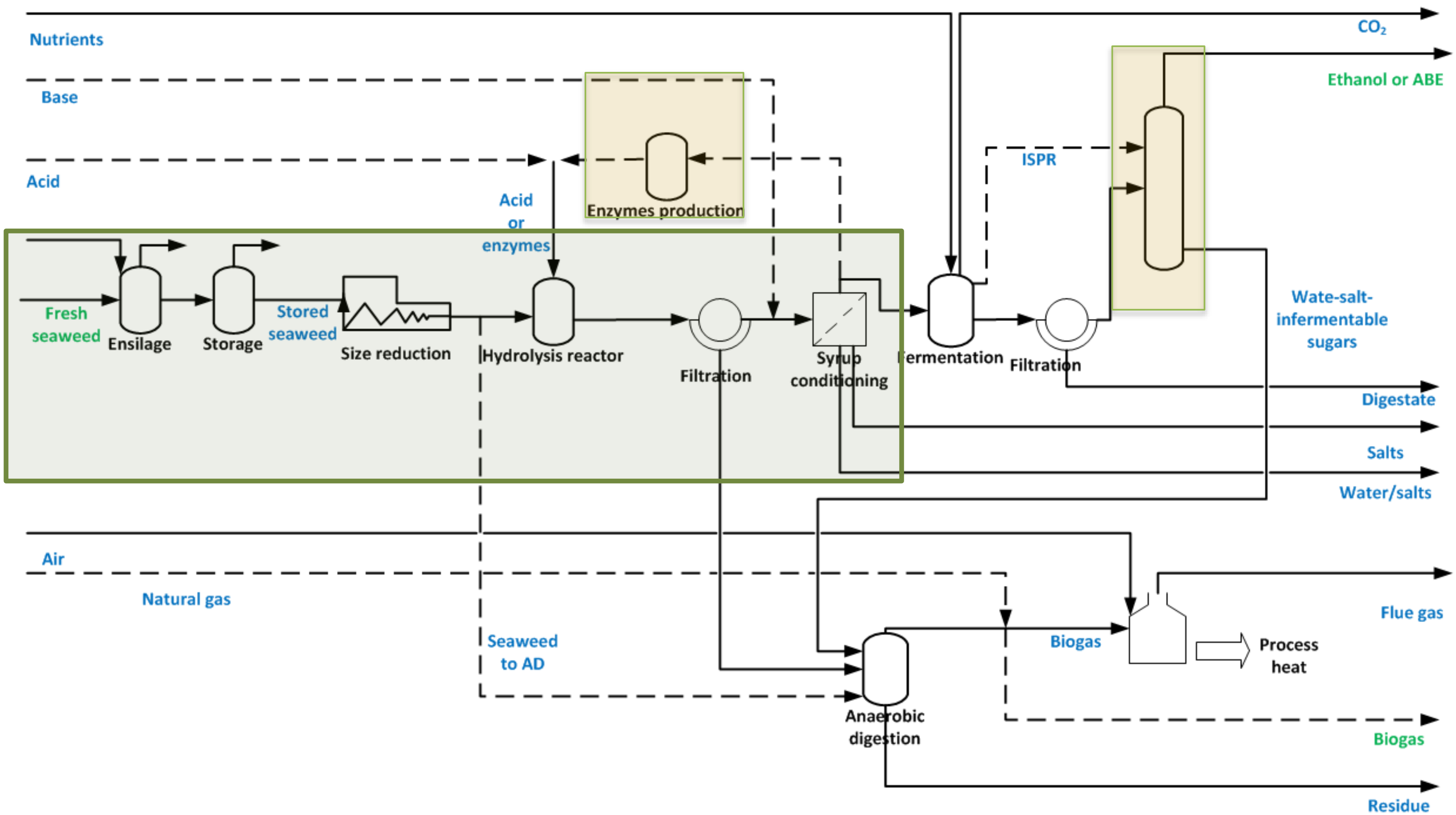

Model

Model objective:
Mass and heat balances aiming at calculating the yield in fuels from seaweed feedstock

Newly developed model, combining approaches for wood fractionation, literature available data.

Modeling approach:

- Steady state model
- Aimed at stoichiometry and heat balance
- Constant composition and conversions
- Model seaweed with its hydrolyzed components
- Model salts as electrolytes (so Na^+ and Cl^- rather than NaCl)

Seaweed model components

Main choice: model seaweed as hydrolyzed components

Saccharina Lat. Fresh, Sams (aug 2016)

Seaweed analysis
- Sugars/organics
- Inorganics
- Ultimate

Model assumptions	
% insoluble protein	50%
% soluble unknown organics	50%
% inorganic sulphur	90%
% Insoluble ash of unknown	90%
% Ca in CaCO3	10%

Total=100%

Excel tool

Charge neutrality

Model component	Mass%
Glucose	4.8
Xylose	0.4
Galactose	0.7
Fucose	1.5
Rhamnose	0.3
Glycerol	0.0
Mannitol	6.5
Galacturonic acid	0.0
Guluronic acid	3.6
Glucoronic acid	1.0
Mannuronic acid	6.2
Iduronic acid	0.0
Protein	6.6
Protein insoluable	6.6
Other water soluable organics	9.3
Water insoluable organics	9.3
Sulphate	3.4
Other org sulphur comp	0.4
Ca2+	5.1
K+	6.0
Na+	5.8
Other anions	20.9
CaCO3	1.4
Other insoluable ash	0.0
Other soluable ash	0.1
Total	100

Ensiling/storage

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- Ensilage workshop in Kopenhagen was very useful
- Main choice: Model reactions and conversion per reaction
- Information on ensilage scarce. Often natural ensiling, not the preferred option for large-scale

- Combining data from two sources → infeasible results, e.g. not enough sugars to reach product components

Ensiling model

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Reaction	Saccharin a lat.	
Glucose → 2 lactic acid	38.8%	Based on ECN measurements, assumed 10% homofermentative,no collostridial
Glucose → lactic acid + ethanol+ CO2	2.2%	Half of homfermentative part
Glucose + H_2O → lactic acid + acetic acid + mannitol + CO_2	2.2%	Half of homfermentative part
Glucose → butyric acid + $2CO_2$ + $2H_2$	0.0%	Assumpe collostridium is sufficently suppressed
Glucose + 0.4 N_2 → 4 LAB + 6 H2 + 5 CO2	1.8%	Based on analogue with ethanol fermentation
Mannitol → Lactic acid + H_2	39.6%	Based on ECN measurements, assumed 90% homofermentative,no collostridial
Mannitol → Acetic acid + H_2 + CO_2	4%	Based on ECN measurements, assumed 90% homofermentative,no collostridial
Rhamnose → Lactic acid + H_2	39.6%	Conversion equal to mannitol
Rhamnose → Acetic acid + 4 H_2 +2 CO_2	4.4%	Conversion equal to mannitol
Glucoronic acid+H_2O→ Acetic acid + 2 CO_2 +2 H_2	0.0%	Assumed zero
2 ORGSUL + H_2O → 10 CO_2 + 18 H_2 + 2 H_2S +N_2	0.0%	Assumed zero

Data from pre/post analysis of hortimare seaweed analysis at ECH

Fractionation and filtration

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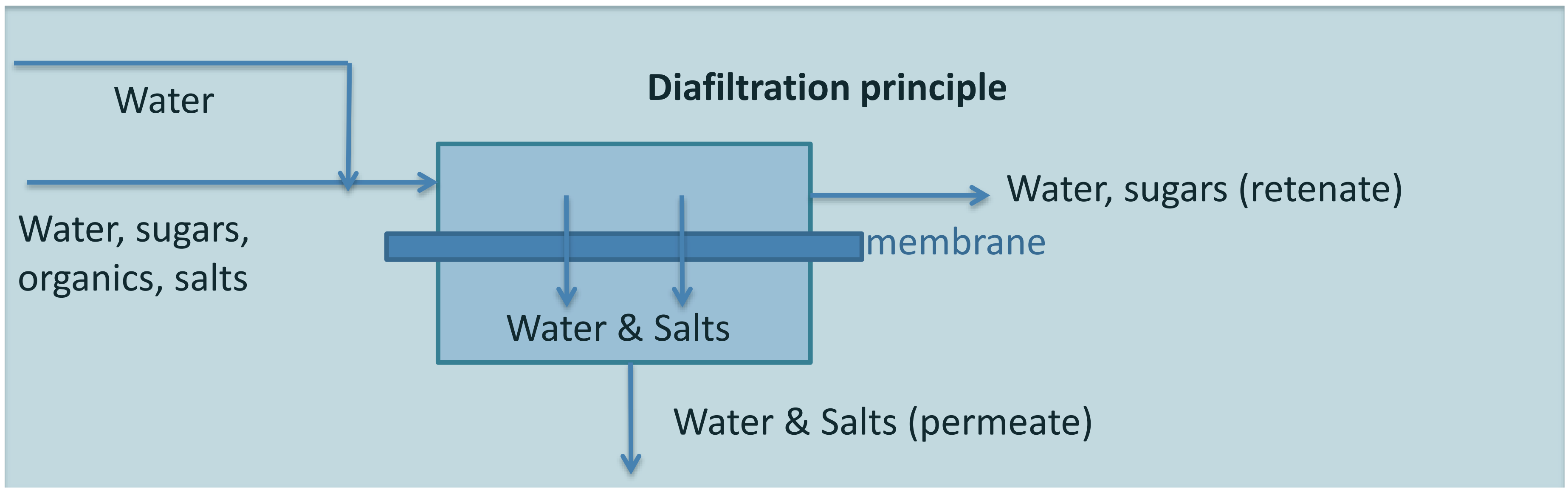
- Reaction
  - Mild acid frationation, yield as in lab
  - Side reaction:

    Glucose → HMF + $3H_2O$ (low conversion)
- Filtration of solids
- Neutralization

Syrup conditoning



- Remove salts & Concentrate syrup

Complex multistage system required

➔ use separator with target values

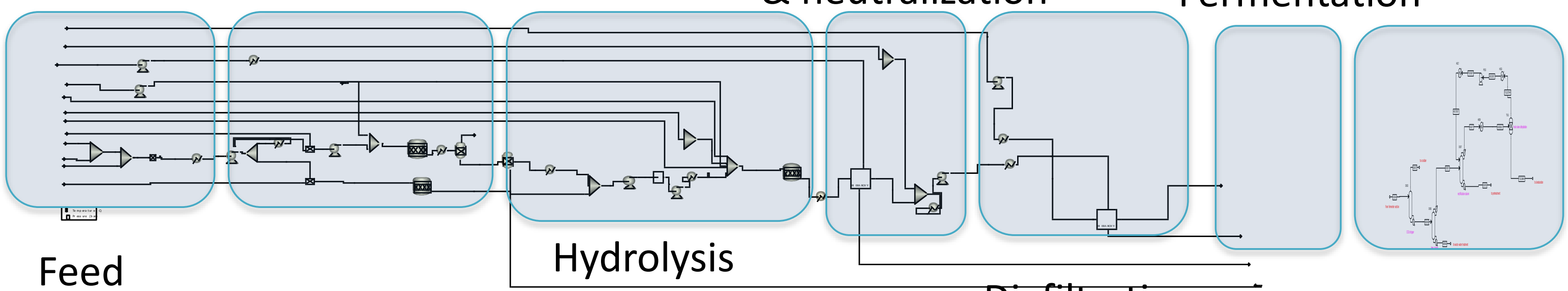
- Salt concentration 10-20 g/l (all salts, 20 taken for now)
- Sugars 60 g/l
- Sugar losses 3%

Implementation results

Insiling

Filtration
& neutralization

Fermentation

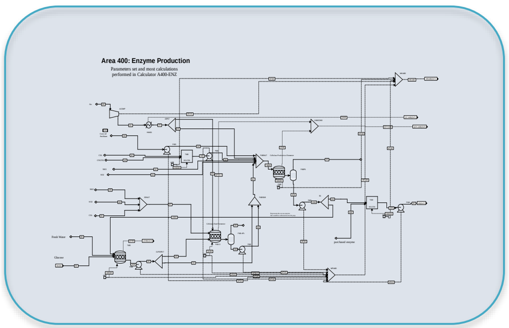


Feed
definition

Hydrolysis

Diafiltration
conditioning

EtOH
distillation



Heat integration

Enzyme production

Anaerobic digestion

Preliminary results

kton/yr	Feed	After ensiling	Neutral Filtrate	From conditioning to fermenter
DW	1200	1210	850	377
Total	6300	6350	6600	1770
Sugars	170	110	104	101
Total organics	690	630	290	287
x_sugars [% mass]	2.7%	1.7%	1.6%	5.8%

Much more sugar loss in ensilage that the target of 5%
Can lactic acid be converted to ethanol in fermantation?

Sugars = glucose + xylose + galactose + fucose + rhamnose + mannitol

Preliminary results

- Only limited data available
  - ➔ have to work with scarce, preliminary and target data
- Seaweed composition modelling satisfactory
- Significant loss in sugars through ensiling
  - ➔ ensiling will be the preferred conservation method so this to expect

Grow-out unit

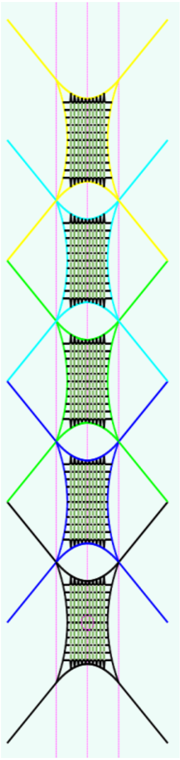
Functional design & concept ➔ parts and amounts ➔ costs

ECN proposal➔Sioen comments

- Rectangular cable design system with ribbon nets.
- Frame is made of cables, with shape control by pre-tension??
- Ribbon nets, are connected in the frame
- At location application of sporophytes
- Reuse of substrate till end-of-life
- Two seaweeds per year
- One-time harvest per seaweed
- Seaweed transport by ship
  (no flexibags etc., this we might evaluate in a later stage)
- On-shore tank for seaweed storage
  (but this will be part of the processing plant design)

Status: Concept and functional design proposed and now at Sioen for comments

Next: for inventory of components modifying tool developed in at~sea



Path forward

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- Finalize model
  - Add sections: fermentation (with DTI), enzyme production, AD
- Heat balance

- ABE fermentation case
  - Upstream identical
  - ABE fermentation (with WUR) and purification (prepared)

- Ulva case
- (Red seaweed to furanics case)
- (Sizing and economics)

WP6.3: Social assessment

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Rita Clancy, Eurida

Objectives

- One important aim is to minimise possible negative social impacts on communities
- Assisting communities and other stakeholders to identify development goals, and ensuring that positive outcomes are maximised, can be more important than minimising harm from negative impacts → Measures for project impact maximisation

Social Impacts

Changes to:

- People's way of life – how they live, work, play and interact with one another on a day-to-day basis
- Culture – shared beliefs, customs, values and language or dialect
- Community – cohesion, stability, character, services and facilities
- Political systems – the extent to which people are able to participate in decisions that affect their lives, the level of democratisation that is taking place, and the resources provided for this purpose

Social Impacts

Changes to:

- Environment – Quality of the air and water people use; the availability and quality of the food they eat; the level of hazard or risk, dust and noise they are exposed to; the adequacy of sanitation, their physical safety, and their access to and control over resources → Input from SAMS
- Health and wellbeing – as a state of complete physical, mental, social and spiritual wellbeing and not merely the absence of disease or infirmity
- Personal and property rights – are people economically affected, or experience personal disadvantage

Social Impacts

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- Fears and aspirations – their perceptions about their safety, their fears about the future of their community, and their aspirations for their future and the future of their children

- ➢ Very important part of SIA, which is difficult to assess. Surveys and personal communication will give ideas about perceptions.
- ➢ Experience with other forms of aquaculture and/or similar usage of marine resources useful.

Tasks Performed

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- Potential activities which may lead to ‘social issues’ were screened
- Stakeholder analysis performed
- Initial ‘Social Impact Canvas’ drafted

Interims results

Critical activities – potential negative impacts/ perceptions

- Cultivation
  - Seaweed threat to other species
  - Amount of seaweed cultivated critical
  - Change of water quality due to aquaculture
  - Competition with fisheries
  - Competition with sea tourism/leisure
  - Lower recreational value of sea/coastal areas

Interims results

Critical activities – potential positive impacts/ perceptions:

- Cultivation
  - Sustainable aquaculture without influx of feed, nutrition
  - Positive benefits from combined farms with fisheries
  - Natural CO_2 and N_2 sinks
  - Seaweed farms could become 'Touristic Attractions'

Interims results

Critical activities – potential negative impacts/ perceptions:

- Harvesting
  - Damage to water quality due to machine harvesting (pollution hazards, spills etc.)
  - Dirt/noise pollution
  - Displacement of labour due to new harvesting techniques
  - Technology requiring higher skills

Interims results

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Critical activities – potential positive impacts/ perceptions:

- Harvesting
  - More efficient with larger yield, more feedstock available
  - Could lead to further sustainable industries (pharmacies, cosmetics, food & feed)
  - ‘Higher skills’ jobs with higher income

Interims results

Critical activities – potential negative impacts/ perceptions:

- Industrial-scale seaweed farming
  - Generally the industrialization of low industry zones
  - Processing industry might follow, new factories, storage facilities etc.
  - Influx of new workforce
  - Impact on traditional community values and cohesion

Interims results

Critical activities – potential positive impacts/ perceptions:

- Industrial-scale seaweed farming
  - Support areas of industrial growth
  - Work place creation
  - Sustainable development of regions with low industries/work places
  - Community revival or stimulation for rather remote or underdeveloped areas

Social Impact Canvas

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Respects that issues are seen differently by different stakeholders

Issue	Stakeholder	Means	Perception	'Facts'
Cultivation	Local resident (without business interest)	Surveys, Meetings, Open Days	Positive/negative	Actual expected project impact
	Local resident (with business interest)	Meetings, Focus Groups	Positive/negative	Actual expected project impact
Harvesting				
Industrial-scale Development				

Outlook: Tasks Month 19-24

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- Continue setting up the Social Impact Canvas
- Conduct semi-structured and informal interviews during stakeholder events to collect details on ‘perception’
- Define the scope of expected impacts on project level (attempt to quantify!)

Challenges: Perceptions of local communities based on non-industrial scale activities;

For industrial-scale impacts data have to be extrapolated;

Levels of uncertainties

Outlook: Tasks Month 19-24

Based on first results:

- Perform a 'Social Impact Risk Assessment'
- Start a 'Social Risk Management' strategy, combined with a 'Social Opportunity Management' plan (Social Innovation Management?)
- Sketch first draft of a 'Social Responsibility' catalogue

  → External social responsibilities form part of MacroFuels' policy recommendations

  → Incl. recommendations and/or actions on skills development and local capacity building

WP6.4: Environmental assessment

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Jonna Meyhoff Fry, ERM

Objectives

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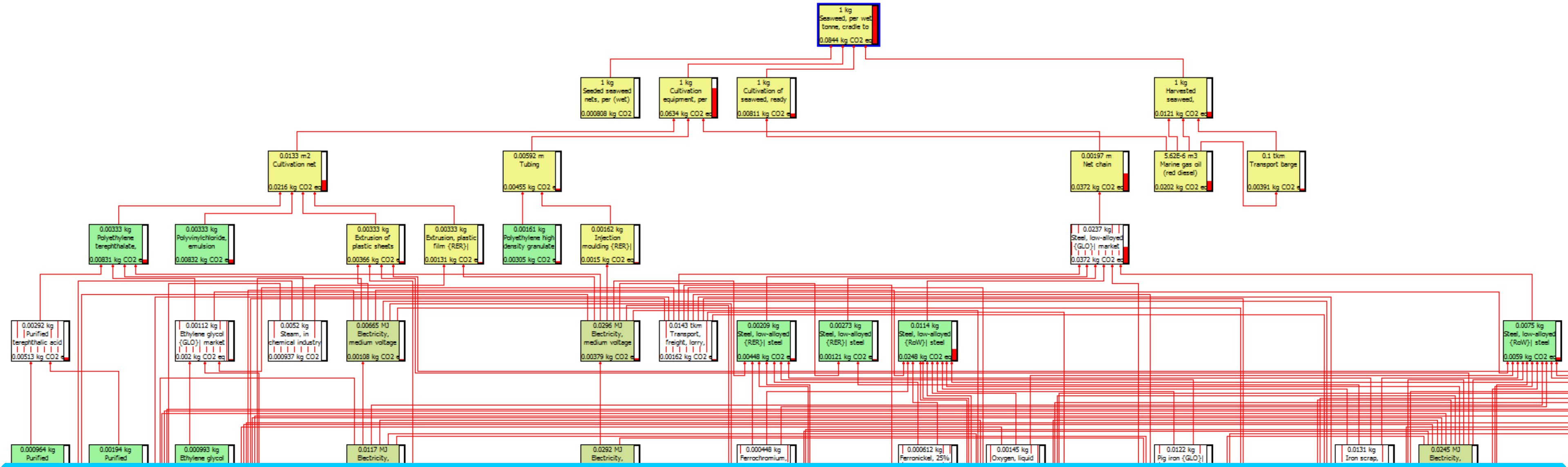
Purpose: Assessment of environmental impacts of the scenarios agreed using environmental Life Cycle Assessment (LCA).

- Where along the biofuel supply chain do the environmental impacts occur?
- How do the different MacroFuels biofuels compare in terms of environmental impacts?
- How do the MacroFuels biofuels compare against environmental data for equivalent conventional, fossil-based, fuels and currently available biofuels?

Tasks Performed

Officially not scheduled to start until M24

Limited modelling and data analysis so far



Environmental Assessment

Modelling and data analysis limited to

- seaweed cultivation
  - numerous assumptions that need to be firmed up
  - numerous variables that can be assessed
    - seaweed yield
    - longevity of cultivation equipment
    - distance to shore
    - visits to site (during grow out period)
    - fuel use by vessel
    - fuel use by harvesting vessel
    - distance to biofuel plant

WP6.5: Environmental and business risk assessment

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AU, SAMS, AVT, SIOEN (M12-40)

Environmental effects

Impact of large-scale seaweed cultivation

- Hydrodynamics
- Light (shading)
- Benthic community (organic matter/oxygen)
- Biodiversity (biofouling, diseases, genetics)
- Ecological Status (EU water framework directive)
- Nutrient extraction and C sequestration

D6.5 Environmental risk assessment

of the Macrofuels concept

The environmental risk assessment will – in co-operation with WP1 - address and assess the direct environmental impacts and risks that large-scale seaweed cultivation may pose at the levels of

- the physical/chemical environment (incl. eutrophication, oxygen)
- biodiversity, e.g. effects on natural seaweed populations (shading, diseases, genetics)
- effects on higher trophic levels (fish, birds and mammals)

- M42 (June 2019)

Monitoring program

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Guideline

- Baseline survey
- Monitoring program during cultivation
- Environmental indicators

Environmental impact at the AU site

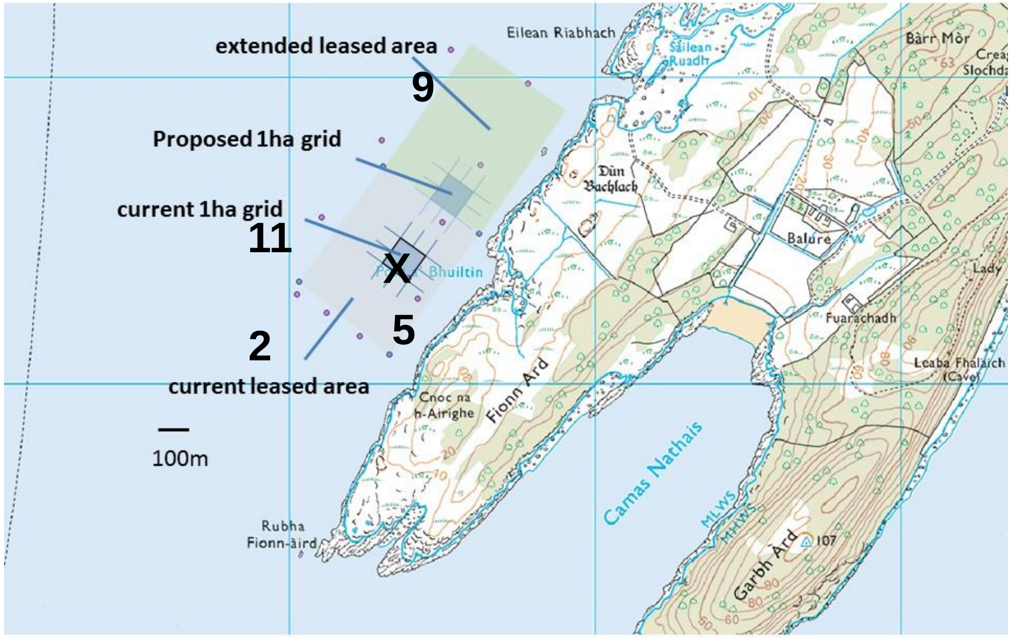
Grenaa:

– Baseline survey (2015)
  - Site & reference site
  - Benthic fauna and sediment (42 cores)
  - Natural vegetation (video transects)
  - CTDs
– Monitoring (ongoing)
  - Light, temperature, salinity (loggers)
  - Water chemistry (nutrients, chl)
  - Benthic fauna and sediment
  - Settling

Close co-operation with National Coastal authorities

Environmental impact of the SAMS seaweed farm

- 5 sites sampled (based on original impact assessment)
- Sampled pre & post harvest (2016 & 2017)
- Sediment (sectioned 8cm cores) & water (T (5m), M (15m), B (30m)) samples collected
  - Water: Nutrients, oxygen, DOC/POC, chlorophyll
  - Sediment: geochem (particle size, chlorophyll, TOC), macrofauna (Grab), microbial
- Go pro & CTD
- Additional routine monitoring of light, temperature & nutrients measured throughout the year
- Repeat above in 2018



Port a Bhuiltin site (SAMS)- 2,5,9, X sample sites

EcoMacro

Ecosystem Impact of large-scale **Macro**algae cultivation

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In-depth snapshot at max biomass standing stock (pre-harvest 2018)

- @ Grenaa & Hjarnø/Aarhus

- Hydrodynamics
- Carbon & nutrient balances
- Climate gasses
- Benthic-pelagic coupling
- Biodiversity

- Danish Centre for Marine Research (k€ 57)
- AU, SAMS, SINTEF, JU

Business risks

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- Implementing large-scale seaweed cultivation
- Storage
- Conversion
- Risk minimisation strategies
- AVT & SIOEN

Acknowledgement

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