SUSTAINABLE ENERGY WEEK

An initiative of the European Commission

17-21 JUNE 2019

EU SUSTAINABLE ENERGY WEEK

SHAPING EUROPE'S ENERGY FUTURE

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Algae aquaculture

Can protein from ocean save land, freshwater and carbon emissions?

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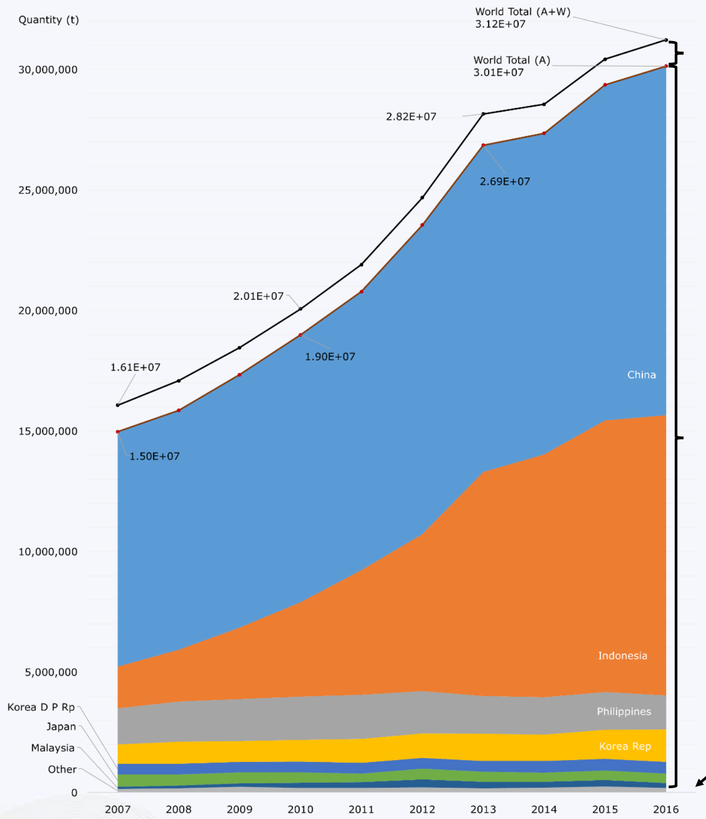
with input from PhD student Xueqian Zhang (xqzh@envs.au.dk)

Global macroalgae production 2016

Wet weight

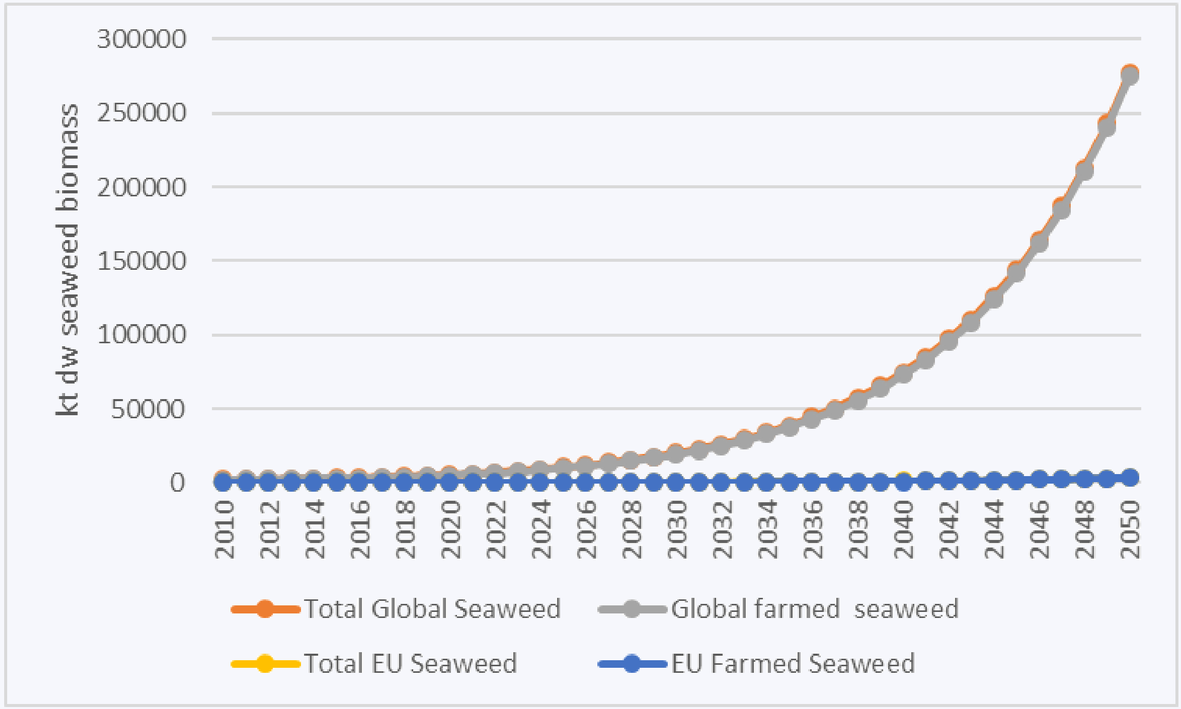


- World total 31.2 Mt
- 30.1 Mt from aquaculture
- 3.5% is wild harvest

- EU total 0.5 Mt
- 3-6% (1.5-3 kt) from aquaculture

Global and European production

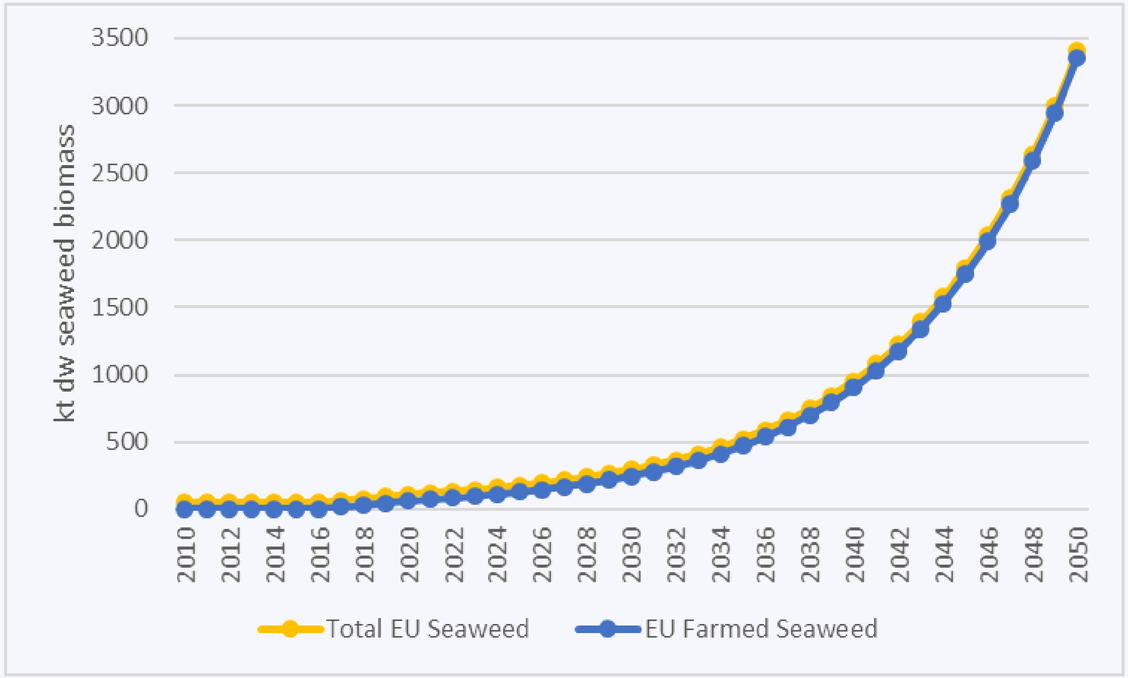
Dry weight (dw) seaweed



- 2016
  - EU total 50 kt
  - Global 3 Mt
- 2050
  - EU production 3500 kt,
  - Global production 300 Mt
- GHG capture at time of harvest
  - -1.9 to -1.9 kg CO_2e / kg dw
- Net GHG capture
  - E.g. –0.2 to -1.3 kg CO_2e / kg dw

Global and European production

Dry weight (dw) seaweed



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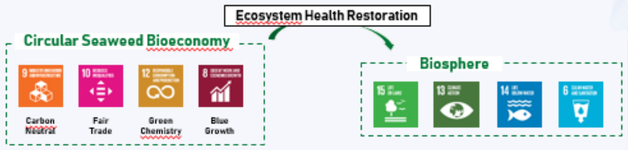
Ecosystem Services

- *Benefit that human obtain from an ecosystem (MEA, 2005)*
- Seaweed **cultivation** +
- Ecoindustrial system =

- **Engineered ecosystem services** mimicking the natural system



Engineered supporting & regulating services

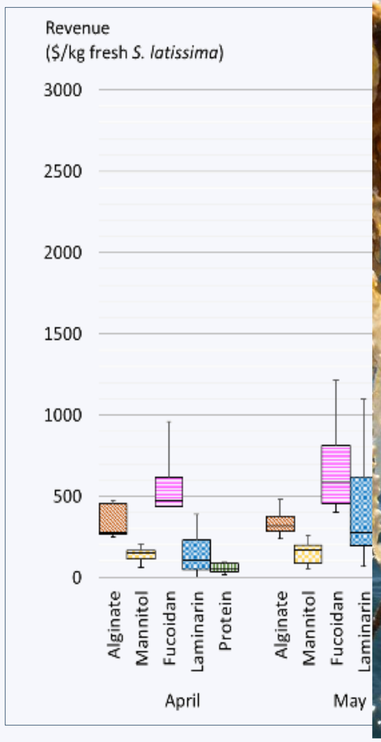
Ecosystem health restoration

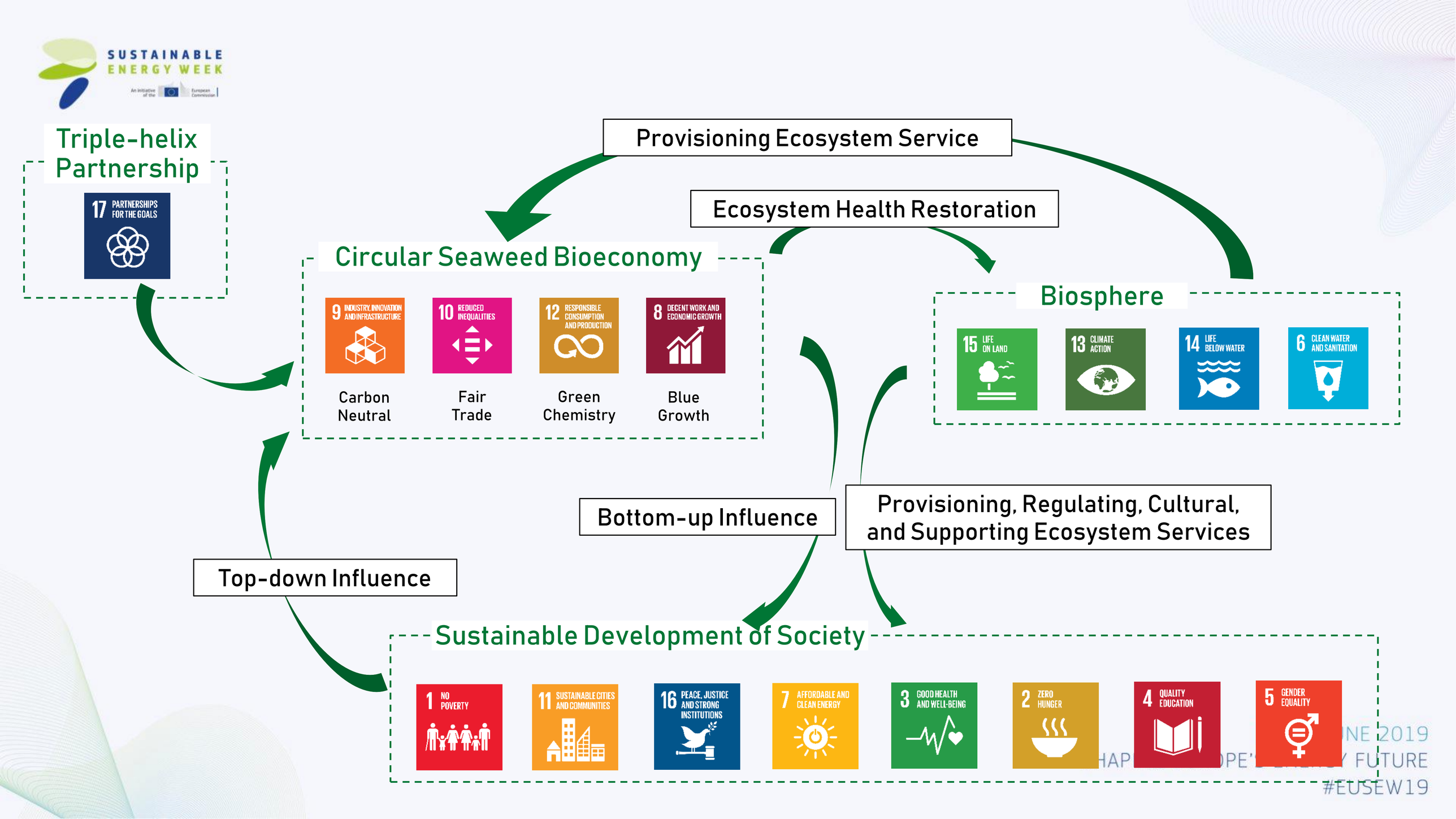
- Water quality restoration
  - Assimilate 20-30 g N/kg dw & 2-3 g P/kg dw
- Climate change mitigation
  - Assimilate 1.3-1.9 kg CO_2e/kg dw
  - Mitigates ocean acidification
- Habitat
  - Attract fish fry during the growth phase

Provisional ecosystem services

Emission capture for biobased production

- Harvested biomass is converted into high value bioactive compounds
- Seaweed derived products substitutes emission-intensive products

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Triple-helix Partnership
17 PARTNERSHIPS FOR THE GOALS
Provisioning Ecosystem Service
Ecosystem Health Restoration
Circular Seaweed Bioeconomy
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
8 DECENT WORK AND ECONOMIC GROWTH
Carbon Neutral
Fair Trade
Green Chemistry
Blue Growth
Biosphere
15 LIFE ON LAND
13 CLIMATE ACTION
14 LIFE BELOW WATER
6 CLEAN WATER AND SANITATION
Bottom-up Influence
Provisioning, Regulating, Cultural, and Supporting Ecosystem Services
Top-down Influence
Sustainable Development of Society
1 NO POVERTY
11 SUSTAINABLE CITIES AND COMMUNITIES
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
7 AFFORDABLE AND CLEAN ENERGY
3 GOOD HEALTH AND WELL-BEING
2 ZERO HUNGER
4 QUALITY EDUCATION
5 GENDER EQUALITY
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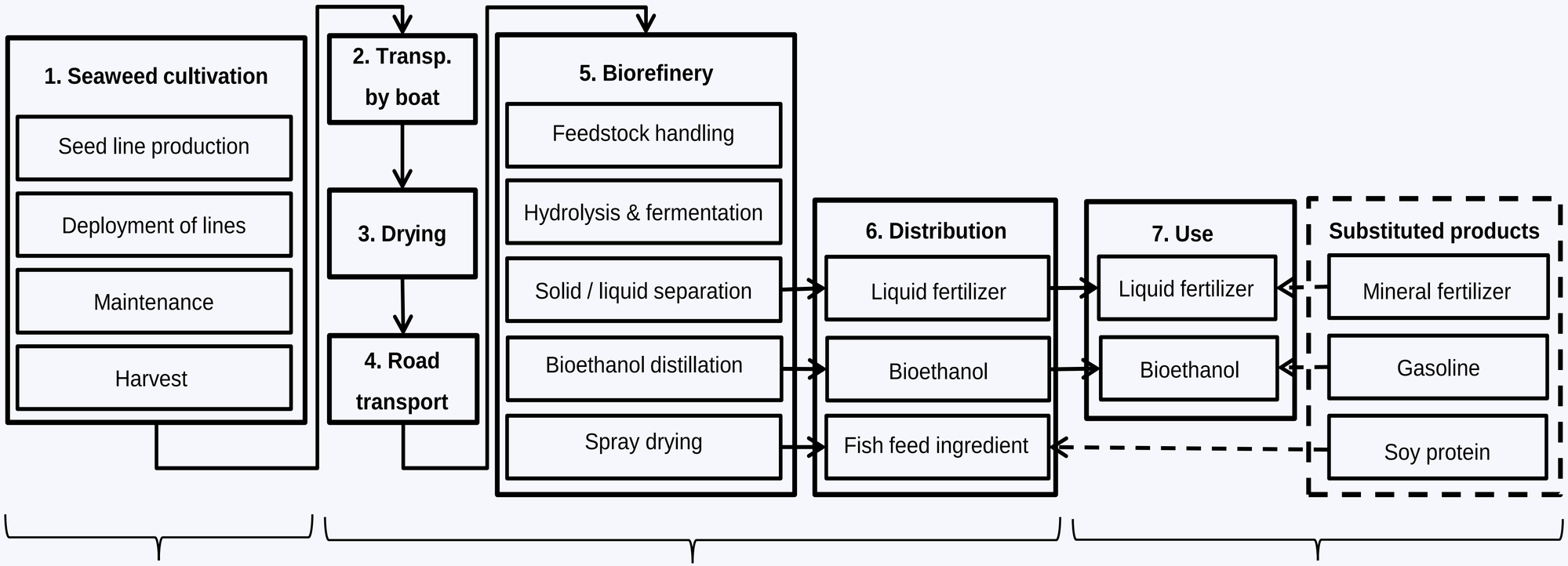
Macroalgal biorefinery system I

Climate neutral ethanol, proteins and fertilizer production



Macroalgal biorefinery system I

Climate neutral ethanol, proteins and fertilizer production

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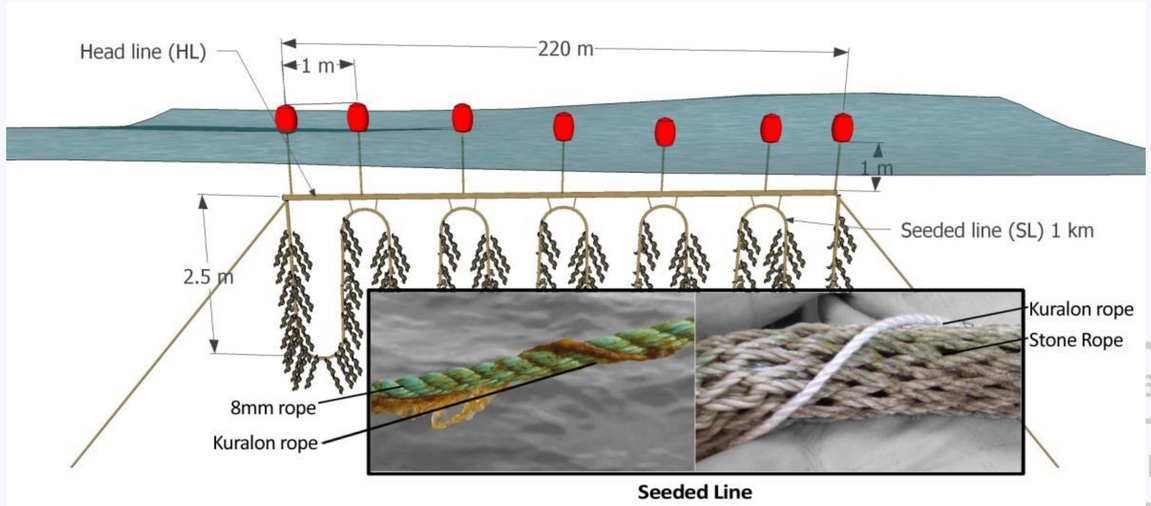
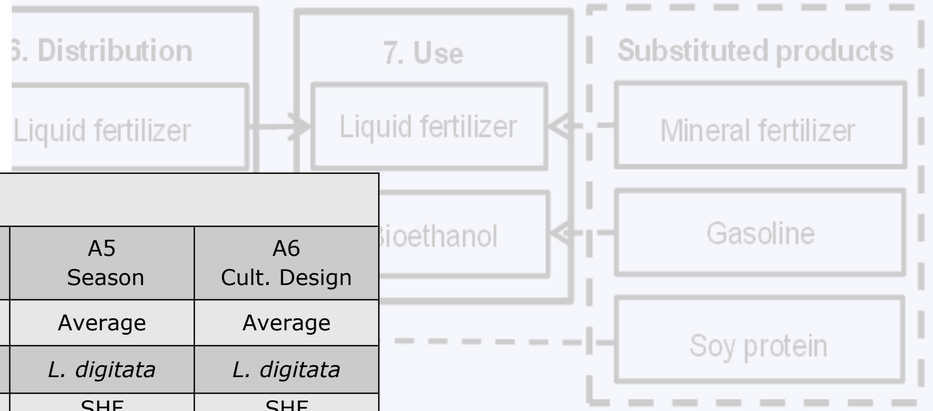
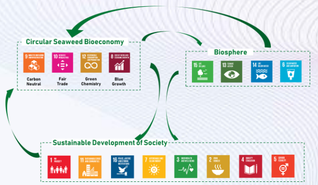
Climate neutral ethanol, proteins and fertilizer production



Seeded Line

Key characteristics	Scenarios						
	BC Base case	A1 Low prod	A2 High Prod	A3 Species	A4 Conversion	A5 Season	A6 Cult. Design
Productivity	Average	Low	High	Average	Average	Average	Average
Species	*L. digitata*	*L. digitata*	*L. digitata*	*S. latissima*	*L. digitata*	*L. digitata*	*L. digitata*
Biorefinery	SHF	SHF	SHF	SHF	SSF	SHF	SHF
Cultivation design	8 mm rope	8 mm rope	8 mm rope	8 mm rope	8 mm rope	8 mm rope	Stone rope
Season	Summer	Summer	Summer	Spring	Summer	Spring	Summer

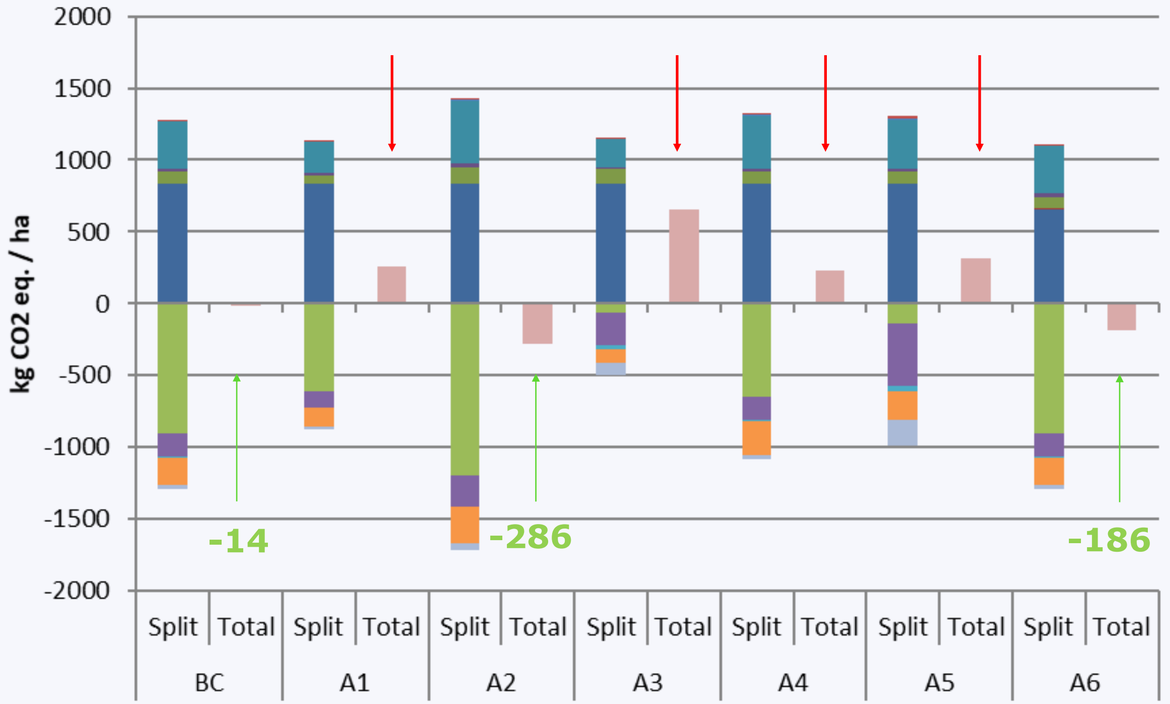




Ethanol, proteins and fertilizers

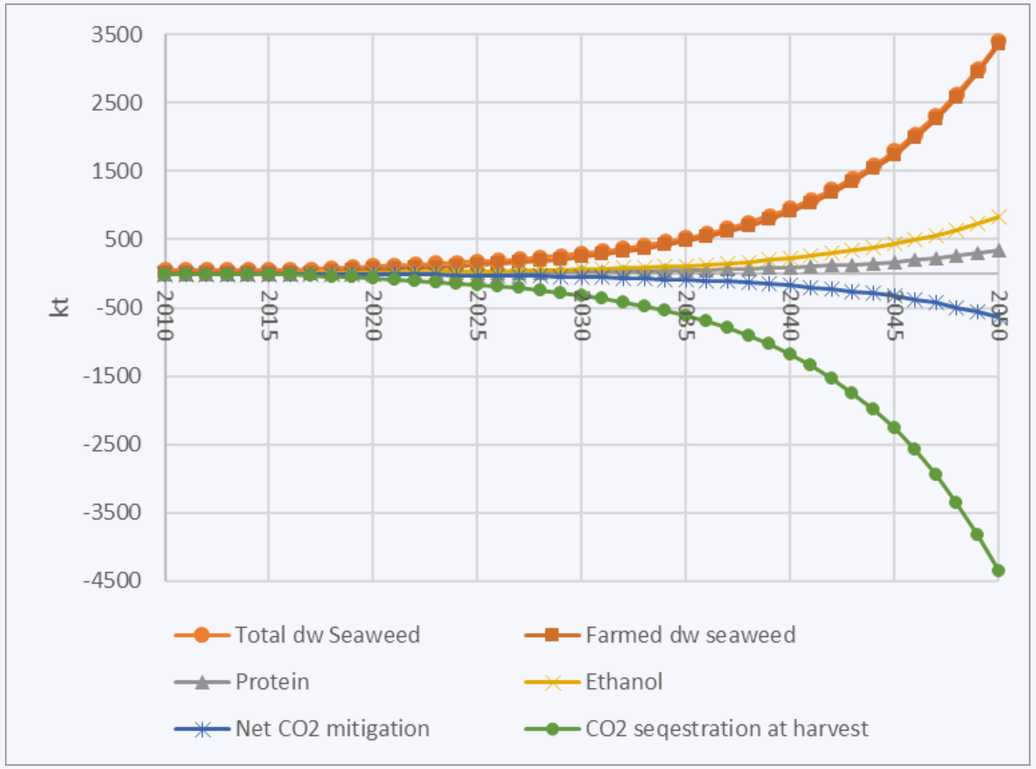
Life Cycle Assessment results

- Net Climate Change emissions ☹
- Net Climate Change **mitigation** services ☺
  - -14 to -285 kg CO_2e per ha



EU level biorefinery system I

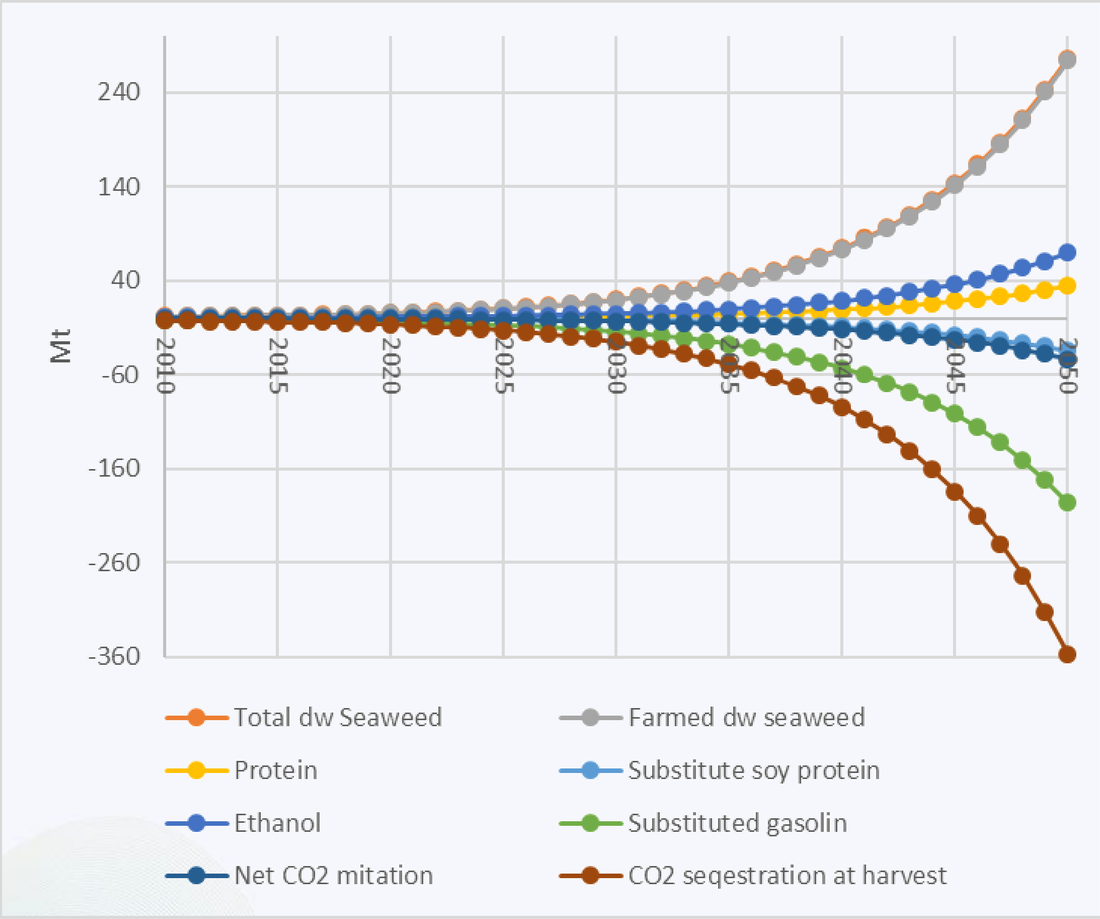
EU scenario - climate neutral production of biofuel and feed



- 2050 < 0.002% of the EU EEZ
- 840 kt ethanol
  - 26% of the energy consumed by light and heavy duty trucks and busses
- 340 kt protein
  - 2-6% of imported crude soy protein
- -640 kt CO_2e capture
  - 15 % of the GHG capture at time of harvest

Global level biorefinery system I

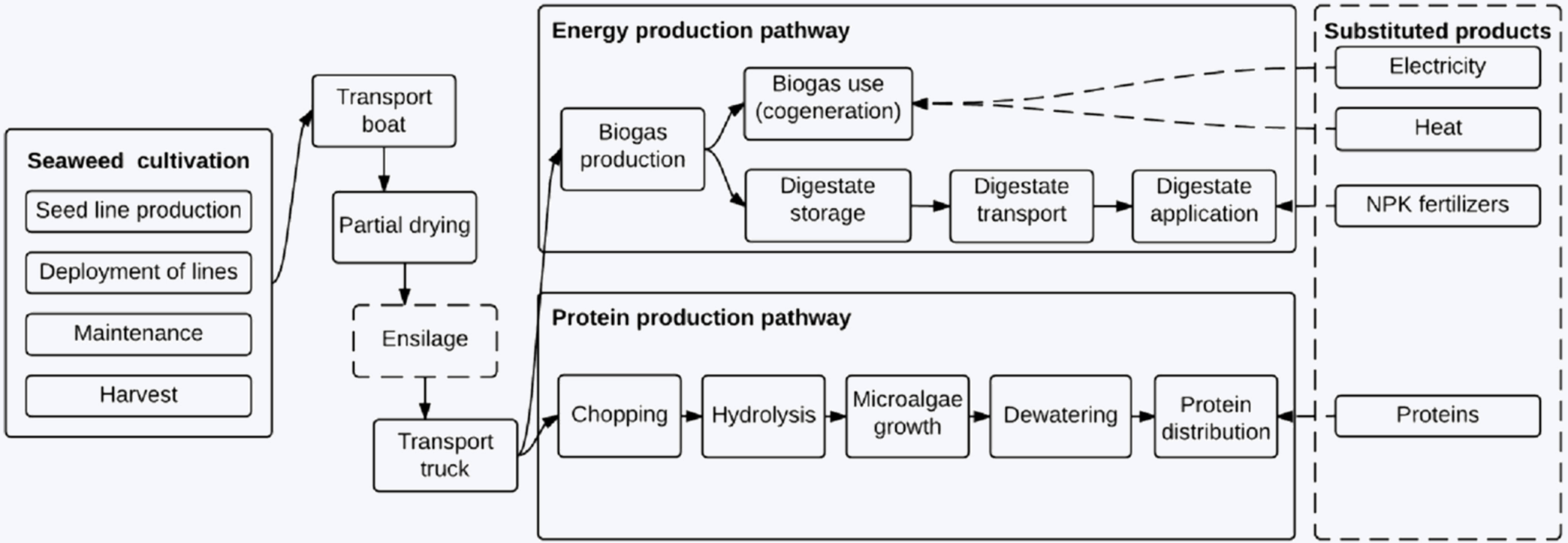
Global scenario - climate neutral production of biofuel and feed



- 2050 < 0.03% of the planets ocean surface area
- 70 Mt ethanol
  - 8 % of EU transport sector energy consumption
- 35 Mt protein
  - A factor 2,5 above the EU imported soy
- -43 Mt CO_2e capture
  - 15 % of the GHG capture at time of harvest

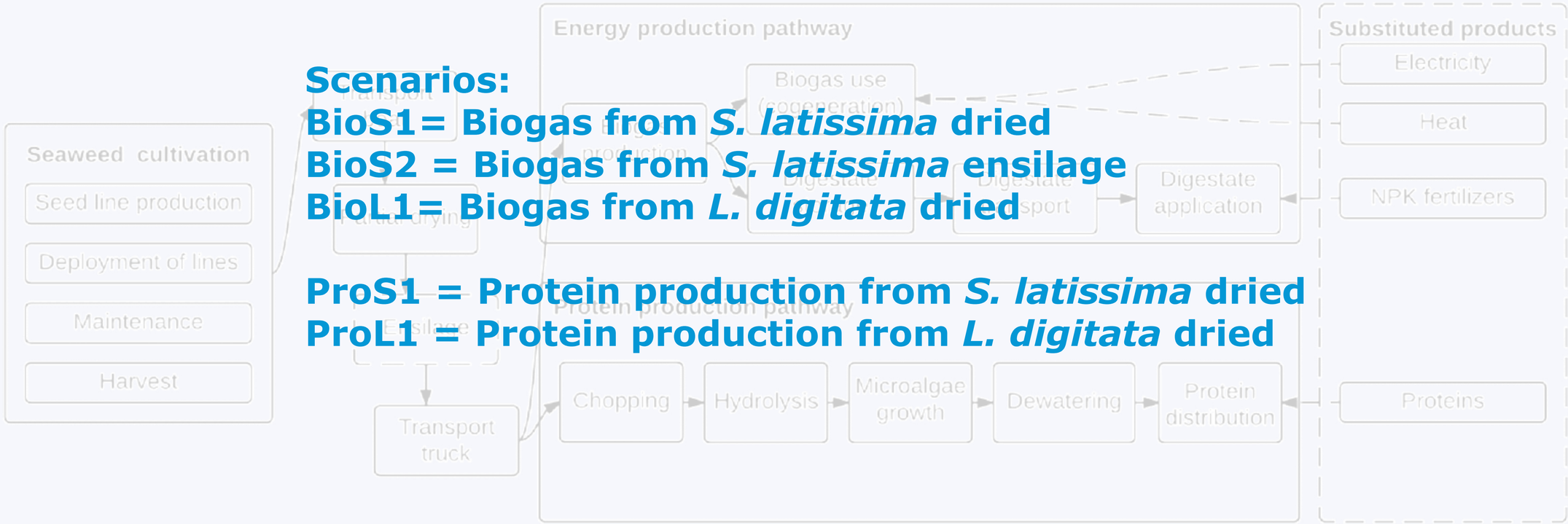
Algae-based production systems II

Energy or feed conversion pathways



Algae-based production systems II

Life Cycle Assessment of conversion pathways



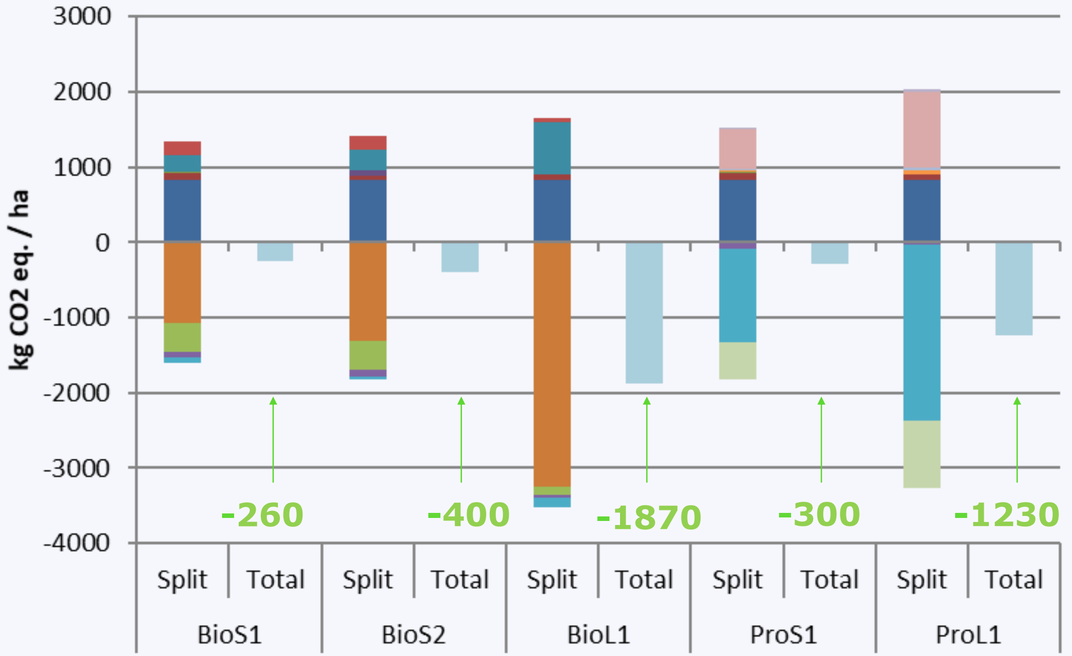
Scenarios:
BioS1= Biogas from *S. latissima* dried
BioS2 = Biogas from *S. latissima* ensilage
BioL1= Biogas from *L. digitata* dried

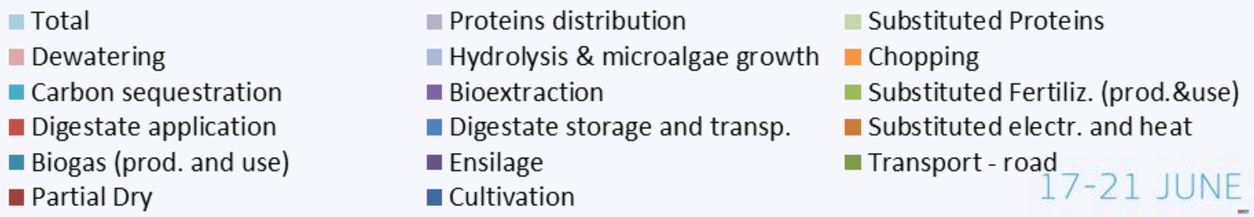
ProS1 = Protein production from *S. latissima* dried
ProL1 = Protein production from *L. digitata* dried

Algae-based production systems II

Life Cycle Assessment results

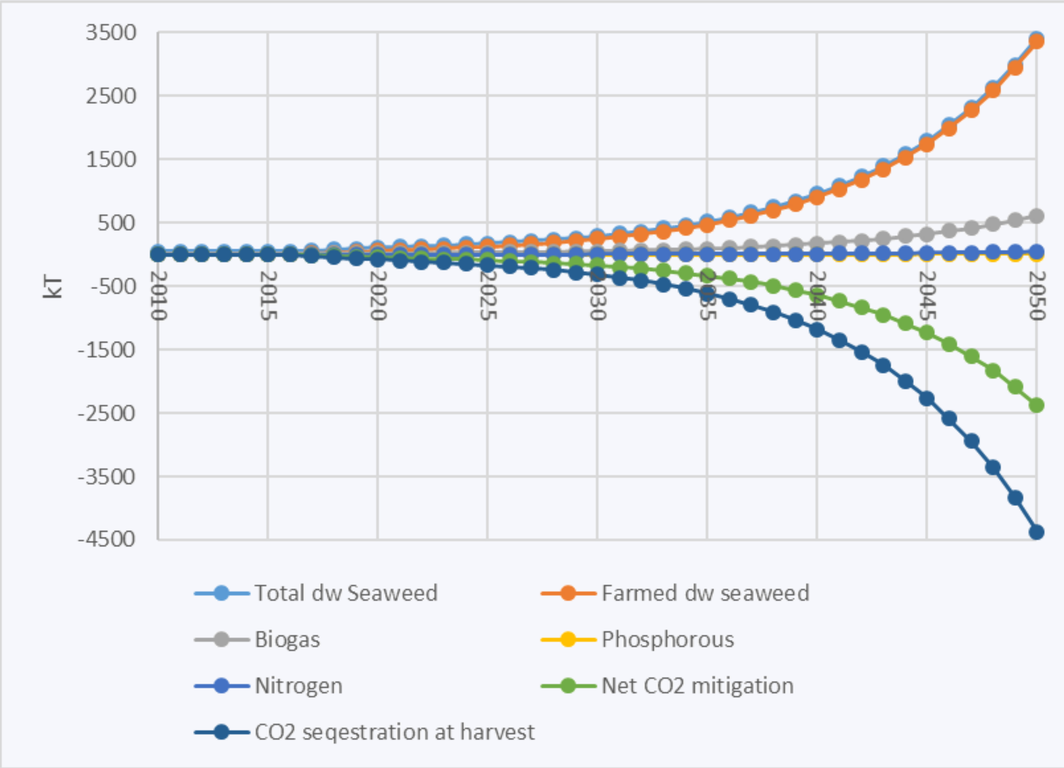
- Net Climate Change mitigation services for all scenarios ☺





Algae-based production systems II

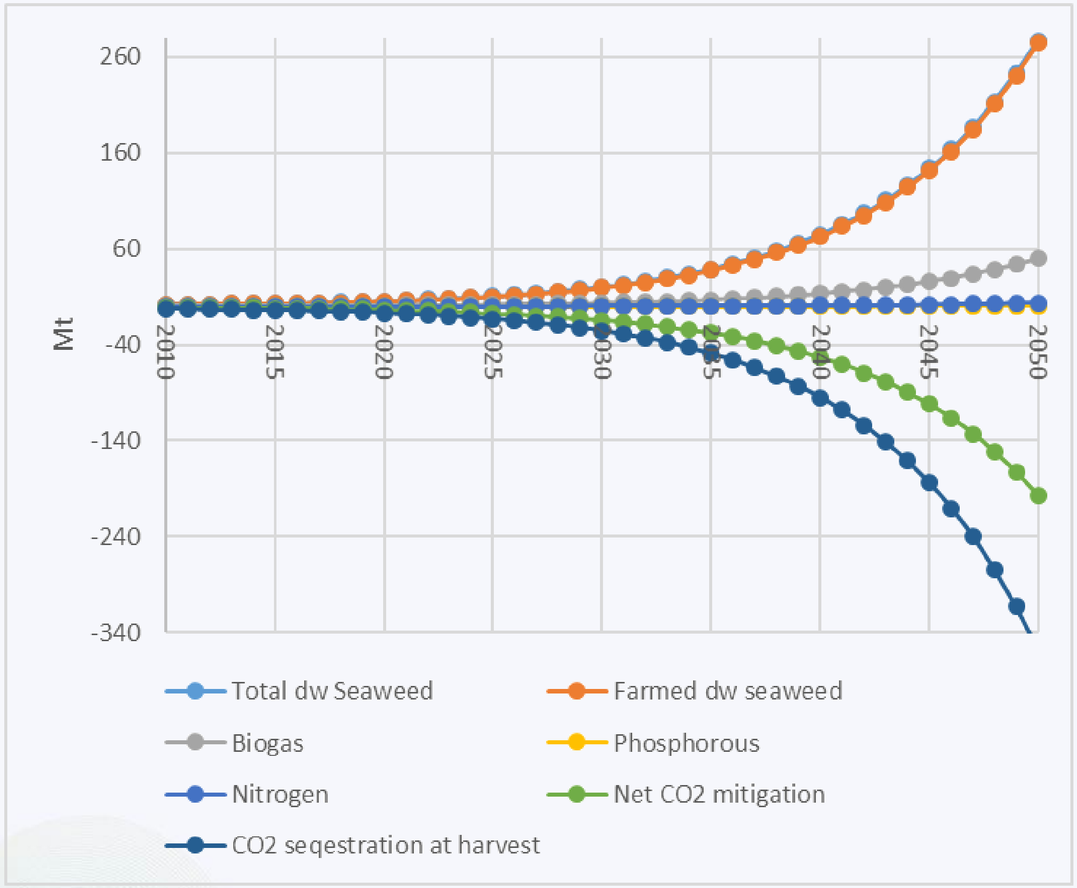
EU scenario - fuel, fertilizer & climate change mitigation



- 2050< 0.002% of the EU EEZ
- 620 kt Biogas
  - 35 % of the energy consumed by light and heavy duty trucks and busses
- Nutrient cycling
  - 50 kt N and 8 kt P removal
- -2400 kt CO_2e capture
  - 55 % of the GHG capture at time of harvest

Algae-based production systems II

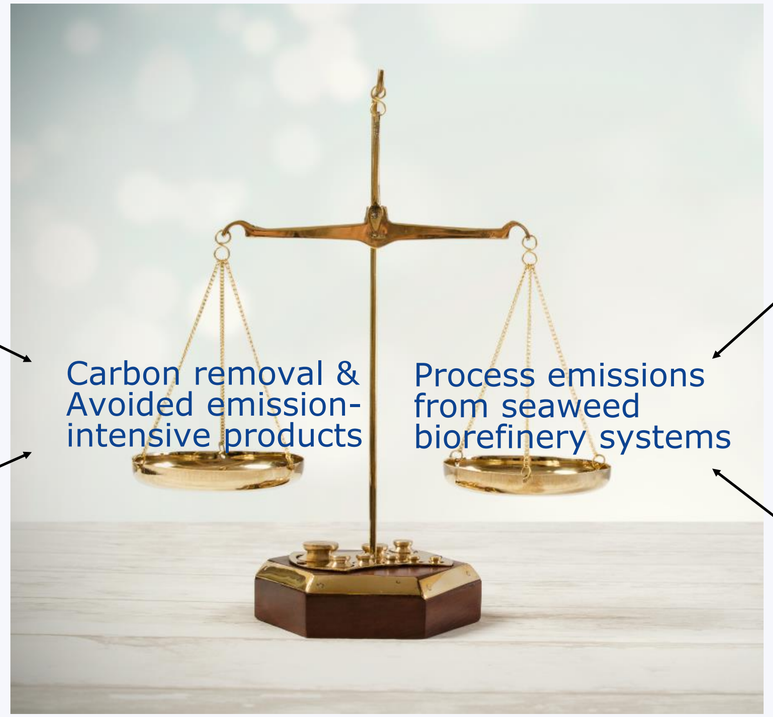
Global scenario - fuel, fertilizer & climate change mitigation

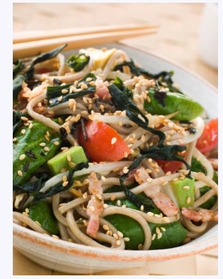


- 2050 < 0.03% of ocean surface area
- 50 Mt Biogas
- Nutrient cycling
  - 4 Mt N and 0.7 Mt P removal
    - 7% of N emission to surface waters
    - 40% of P emission to surface waters
- -200 Mt CO_2e capture
  - 55 % of the GHG capture at time of harvest

Seaweed biorefinery products

Decarbonizing of the economy ?





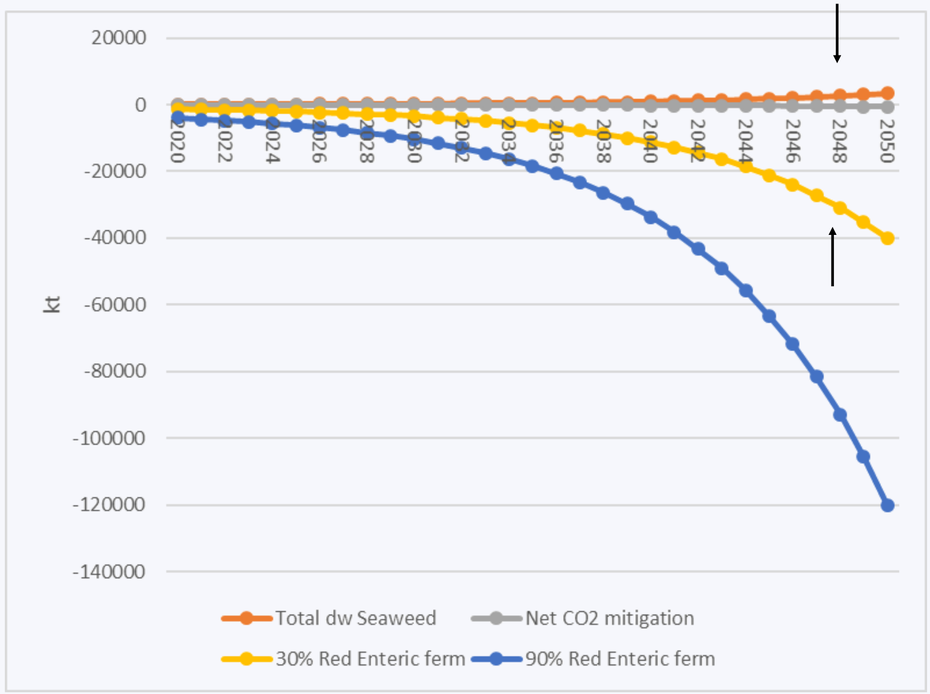
The agricultural sector

CO_2e emission reduction from Climate feed

- 10% of the total EU CO_2e emissions (439 Mt CO_2e)
- 45% of the emission from the agricultural sector originate from **enteric fermentation** 195 Mt CO_2e (7.8 Mt CH_4)
- Algae based climate feed additive for methane reduction in dairy cows
- 2% feed supplement by dw mass
- 30% emission reduction

A climate resilient feed

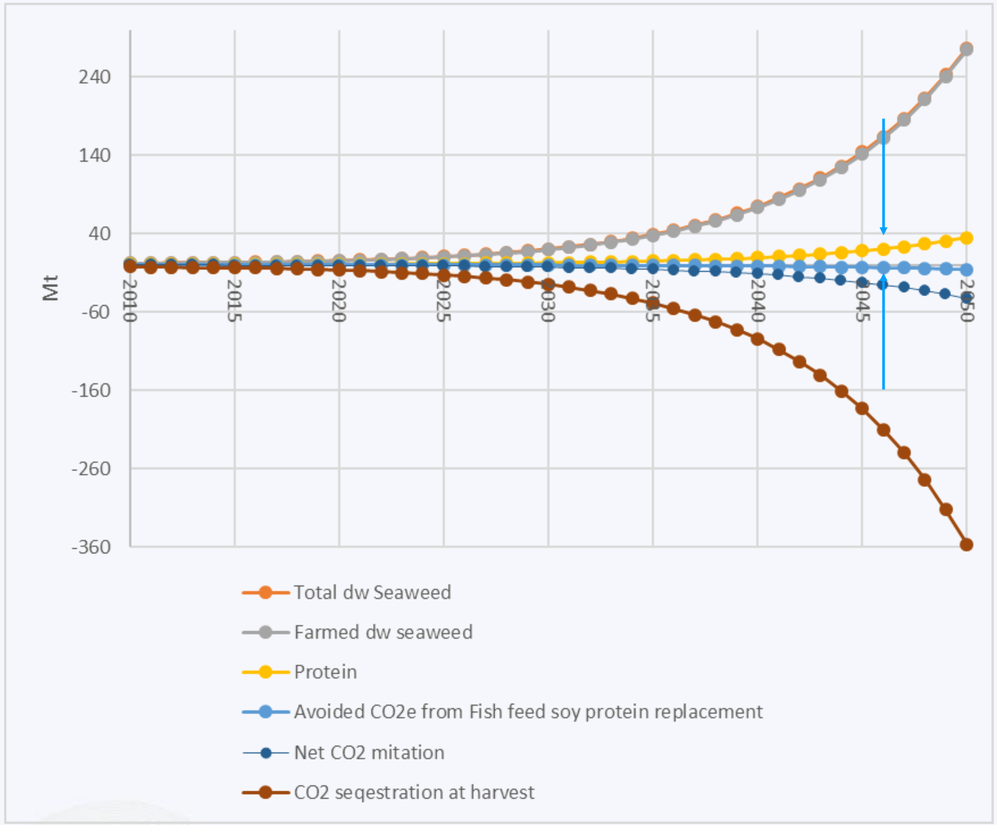
EU scenario -Reducing enteric fermentation



- EU raw milk production (2017) 170 Mt
  - 2700 kt dw seaweed needed (by 2048)
- 1.2 Mt avoided CH_4 emissions (30 Mt CO_2e)
- 10-50% reduction of the total emission from the agricultural sector

A climate change mitigating fish feed

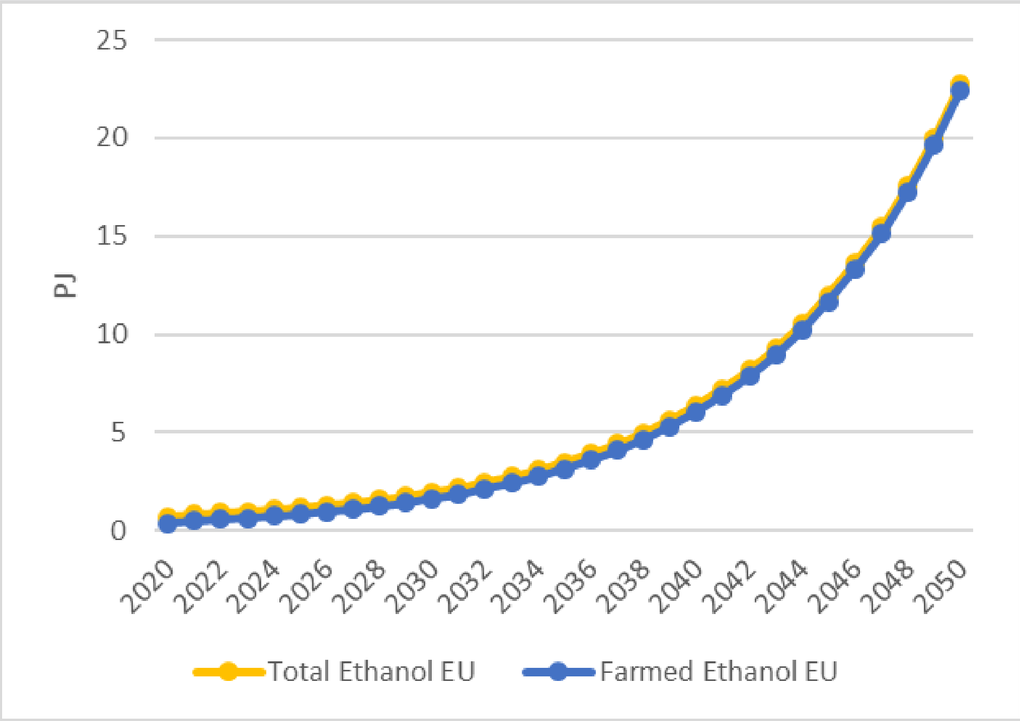
Global scenario - Soy protein substitution



- Substituting imported soy protein to EU with algae protein (14 MT)
- Avoided emissions from soybean production
  - at 100% elimination of soy protein in EU feed -2.4 Mt CO_2e (avoided)
- System level approach
  - 100% soy protein substitution with algae-based protein result in a net negative emission of -17,5 Mt CO_2e

The energy sector

EU scenario - emission reductions from substitution of gasoline



- EU 22 TJ in 2050
- 25% of the 2017 gasoline consumption by light and heavy duty trucks and busses

Conclusion 1/3

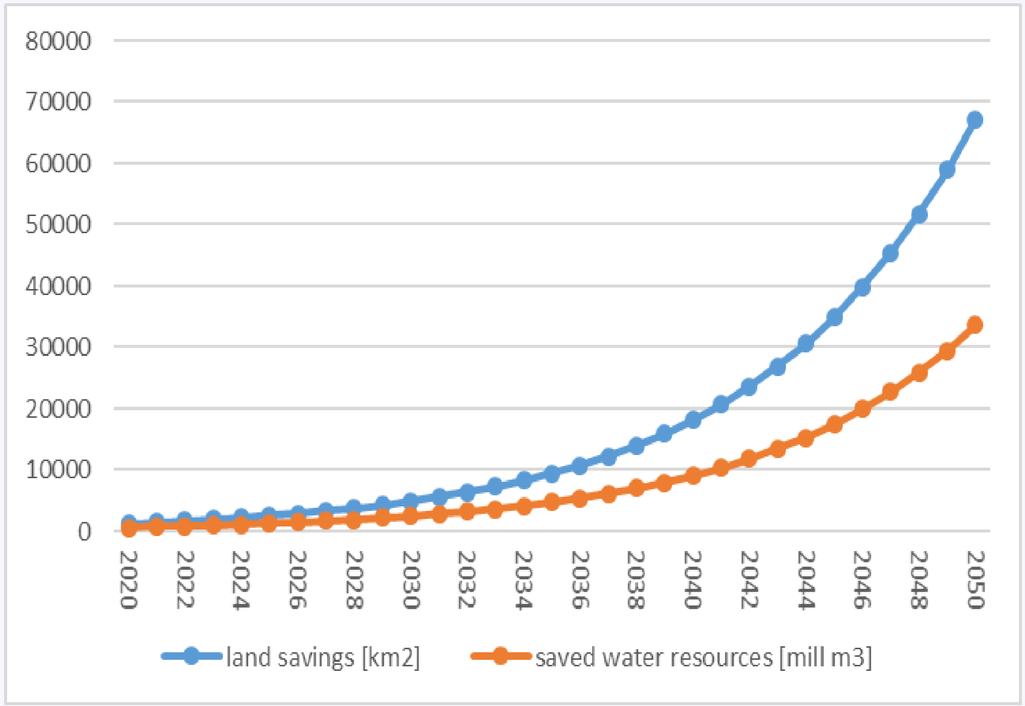
Pathway to a Climate neutral Economy

- Production of farmed seaweed as a **GHG removal technology**
  - Market entry of **climate neutral** seaweed biorefinery **products**
  - **Substitution** of emission intensive production systems

- Agricultural Sectors
  - 10-50% reduction of emission intensity of the agricultural sector
- Energy Sector
  - <1% reduction of emission intensity of the transport sector
- Blue Economy Sector
  - Unexplored potential for GHG capture, storage and use for production of high value biomolecules

Conclusions – not to forget 2/3

Yes! protein from ocean can save land, freshwater in addition to carbon emissions



- 4% of the EU total agricultural area (1.8 mill km^2) could be saved in an EU seaweed self-supply scenario
- 30-64% of the EU total irrigated agricultural area (0.1 mill km^2) could be saved in an EU seaweed self-supply scenario
- In a seaweed import scenario land saving may be significantly higher

Conclusions 3/3

- Valorization of regulating and supporting engineered ecosystem services that is provided to the marine environment is important!
  - Climate change mitigation (CO_2e assimilation)
  - Water quality restoration (carbon and nutrient capture and use)
  - Service revenue to support the income of seaweed farmers
- Appropriate regulations to allow the sector to grow

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