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Cultivation of seaweed biomass for nutrients and energy

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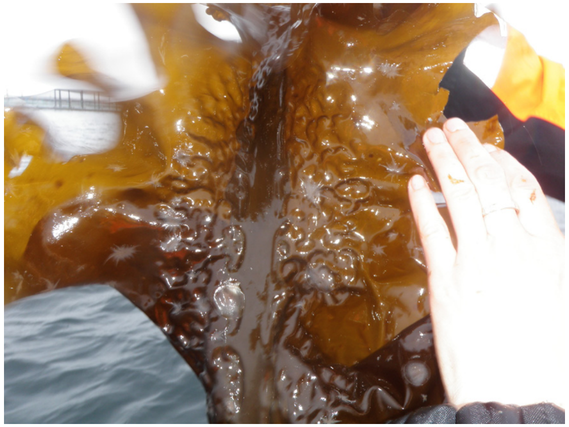
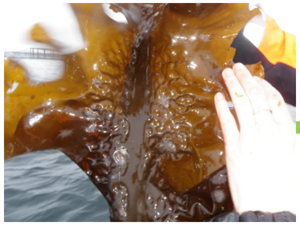
SINTEF Fiskeri og havbruk AS



Seaweeds

- The largest unexploited biomass feed stock?

Biobased products: Marked potential



Global market: Feed additives (amino acids & enzymes) ~7 Mrd US$

Market for pre-treatment chemicals: 10 Mrd $ by 2020

- Bulk chemicals: ~25 Mrd $ by 2017
- Fine & Speciality Chemicals: EU 4 Mrd $; US 6 Mrd $, app 10 increase/a
- Bioplastics: US ~3 Mrd $

Energy: 15,5 TWh
US: 65 Mrd $ Heat & Power

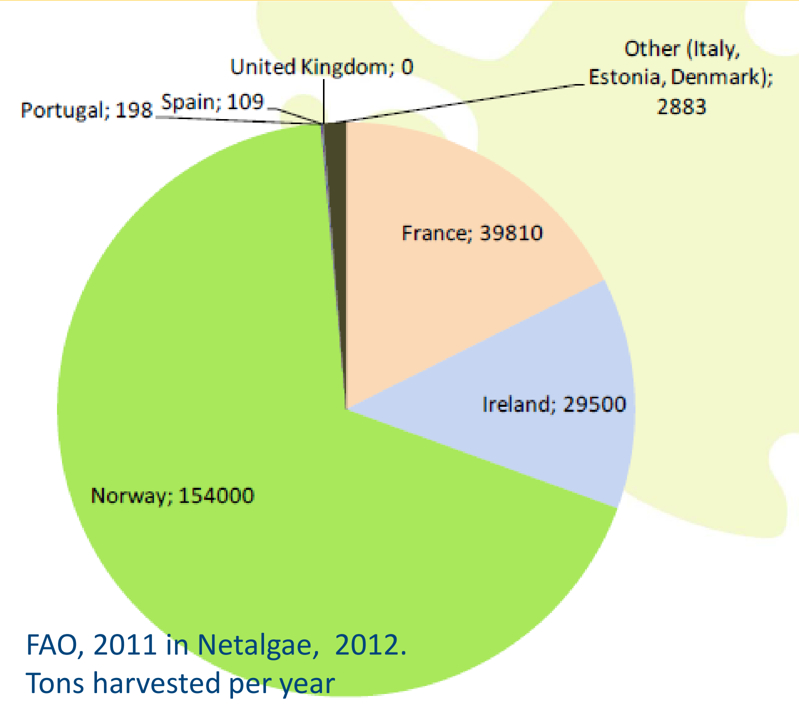
Biofuels: 1,6 TWh (e.g. 70 Mm^3 bioethanol)

Total global market for Biorefinery value chain: ~300 Mrd $ by 2020

(SINTEF Priority Project: Bio-based products from sustainable resources)

Seaweed industry in Norway

- 2 species (*L.hyperborea* and *A.nodosum*)
- 2 companies
  - FMC Biopolymer: Alginate
  - Algea: Meal, bioactive extracts for feed, health food, cosmetics and fertilizers
- Economic value (2011): 1,2 Mrd NOK
- New (not yet in commercial business):
  - Seaweed Energy Solutions
  - Ocean Forest



FAO, 2011 in Netalgae, 2012.
Tons harvested per year

Why cultivated biomass?

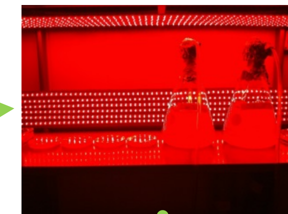
- Attractive biomass (composition affected by season and age)
- Sustainable production of biomass, no negative effect on the benthic ecosystem
- Large volumes possible
- Effective harvesting and freshness of biomass
- Possibilities for nutrients recycling (IMTA)
- 480 species in Norway

Seedlings production – Sugar kelp *Saccharina latissima*

Step 1: Induction of sorus (6-12 weeks)

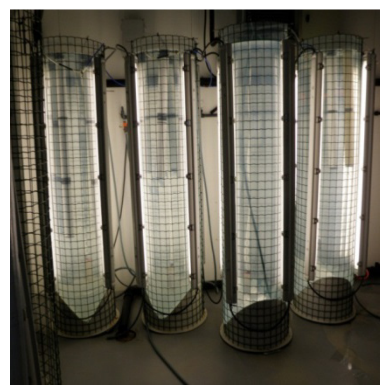
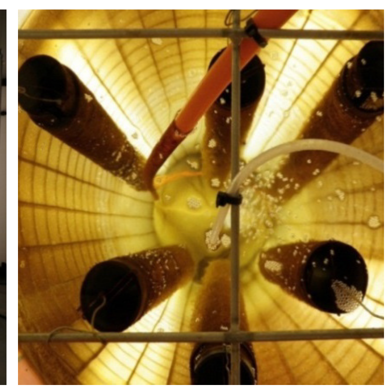
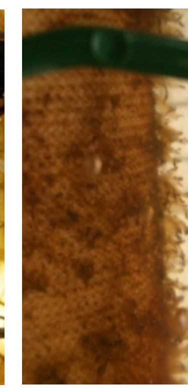

Step 2: Dehydration and spore release (24 h)


Gametophyte cultures



Step 3: Spraying and incubation (~ 2 months)



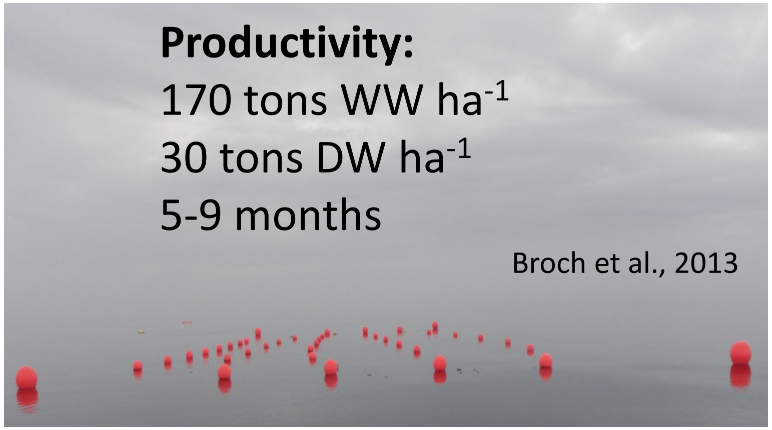




Forbord et al., J.App.Phycol. 2012

Cultivation systems in the sea

Productivity:
170 tons WW ha^{-1}
30 tons DW ha^{-1}
5-9 months

Broch et al., 2013

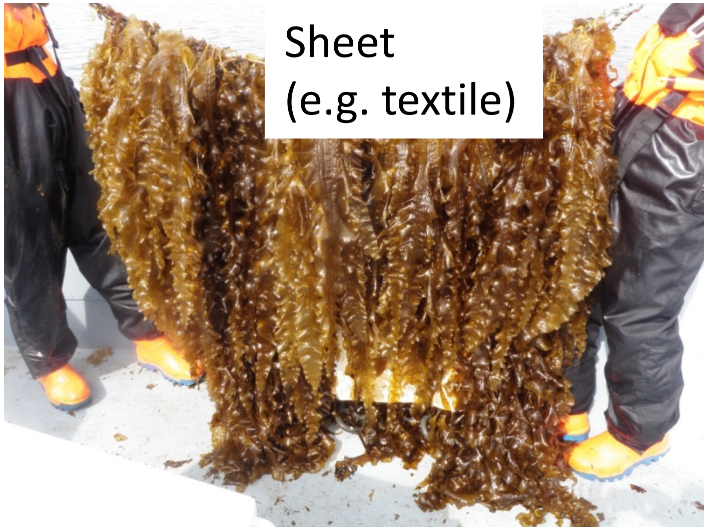


Horizontal lines
(on longlines)

Vertical lines
(on longlines)

Carrier

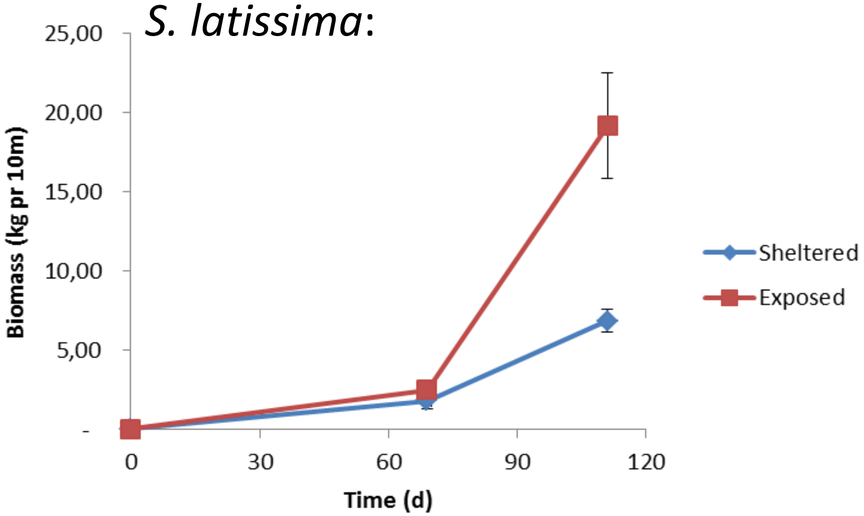
Sheet
(e.g. textile)



Cultivation strategies

- Environmental conditions
  - Water currents and waves, light and depth, day length, nutrient supply and IMTA
- Seasonal effects
  - Chemical composition and bio-fouling
  - Timing and method for seeding and harvesting

Effect of water currents on *S. latissima*:

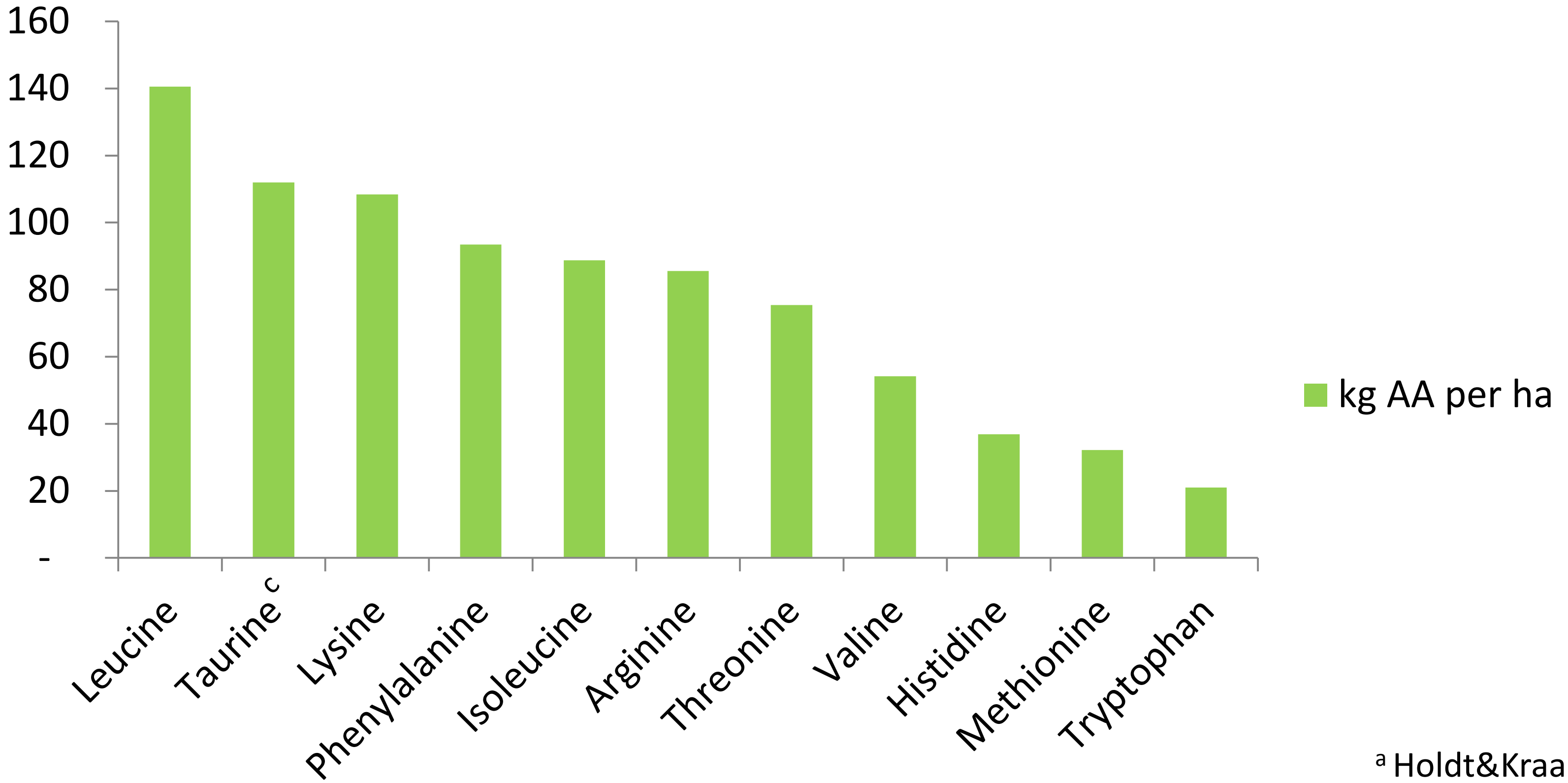


Application for nutrients and energy

- Dry matter (6-39%)
- Nutrients
  - Proteins and amino acids (17-44%)
  - Bioactive components: fucoidan, fucoxanthin, laminaran (β-1,3 glucan), mannitol, alginic acids and high-M alginate, ulvan
  - Pigments, antioxidants, vitamins and minerals
  - Lipid levels are low (up to 4.5%)
  - Polyphenols

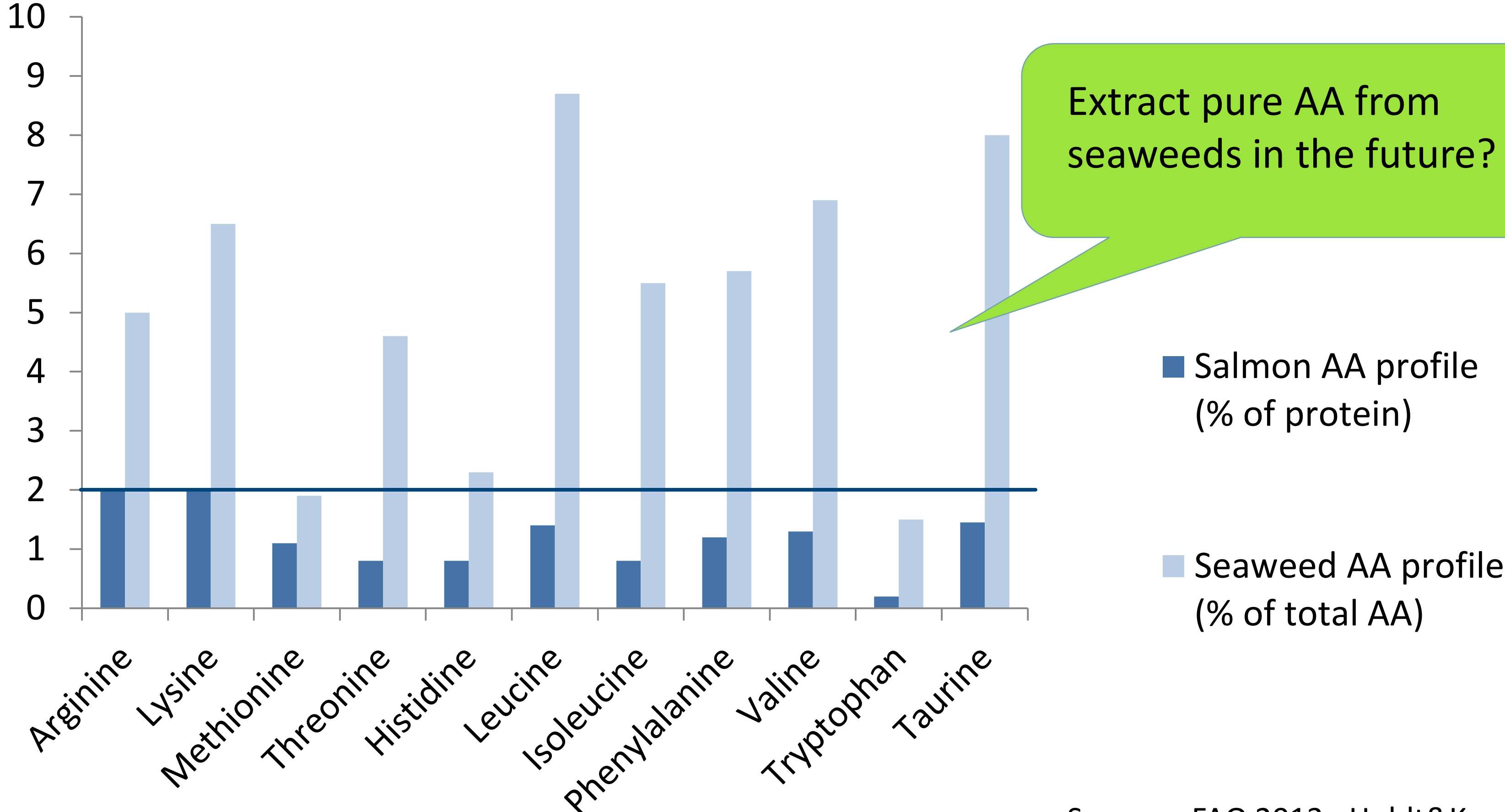
- Energy
  - Carbohydrate fraction (up to 60%)

Potential amino acid (AA) outcome from cultivated biomass of *S. latissima* [a]



[a] Holdt&Kraan 2011
[b] Broch et al 2013
[c] not essential or true AA

Nutritional requirements in salmon
vs.
nutritional value of seaweed *S. latissima* protein



Extract pure AA from seaweeds in the future?

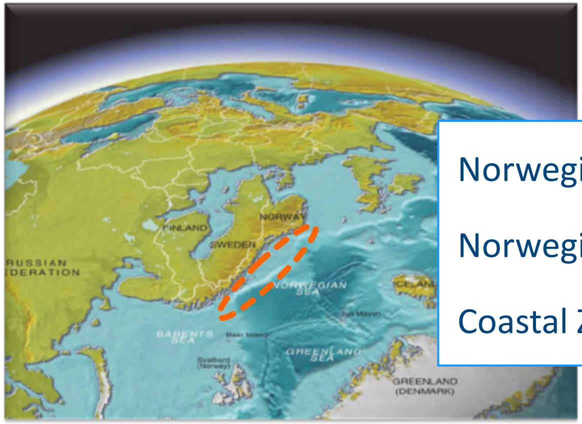
Sources: FAO 2013; Holdt&Kraan 2011

Why extract?

- Enables a better nutrients balance, reduces waste
- Full utilization of raw material as rest fractions can be further processed - **biorefinery**
- Brown seaweeds, rich in demanded components, have high phenol content, that lowers digestibility of whole seaweed
- Traceability regulations will require a complete description of the ingredient(s) when used in feed and food
- Pure extracts lower the risk for harmful side-effects, allows for higher inclusion

Protein and AA yield from cultivated kelp

- Production potential in Norway?



Norwegian coast line: 103.000 km

Norwegian Economical Coastal Zone: 788.000 km^2

Coastal Zone within Sea boundary: 89.000 km^2

- Presently Norwegian salmon aquaculture produces 1.2 million tons yr^{-1} using 800 km^2
- Using a **similar area** for macroalgae cultivation will yield 7 million tons yr^{-1}

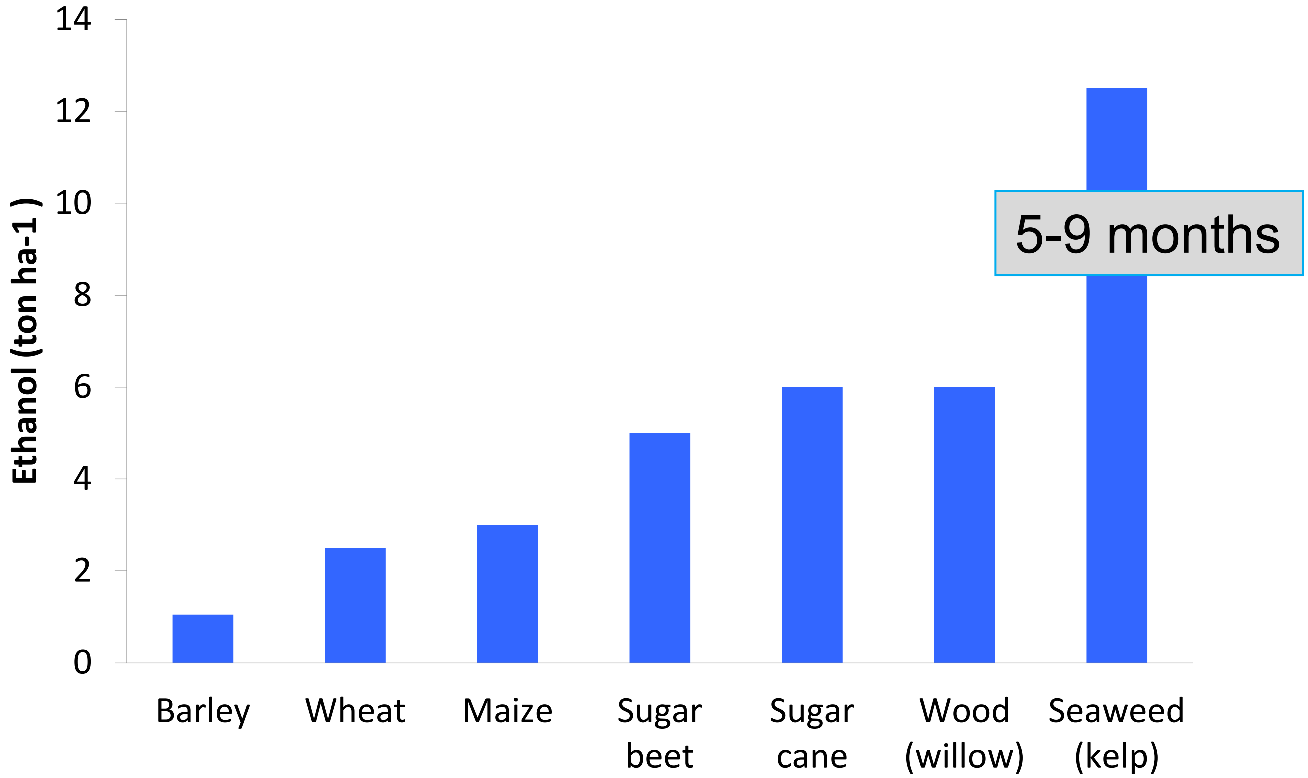
↓

- **7.000.000 tons wet weight**
- 1.050.000 tons dry matter
- 630.000 tons carbohydrate
- 210.000 tons protein
- **70.000 tons amino acids**

Seaweed for 3rd generations bioenergy

- Up to 60% carbohydrates (of DW)
- High biomass productivity (ca 2 kg C m^{-2} $year^{-1}$) (Lüning 1990).
- CO_2-consumption: 8-10 tons per ha per year (Chung et al. 2010)
- No use of valuable human food crops
- No use of productive land area
- No need for irrigation
- No pesticides
- No artificial fertilizers (NB! No phosphate)
- No lignin

Ethanol potential in seaweeds (kelp) vs. other energy crops

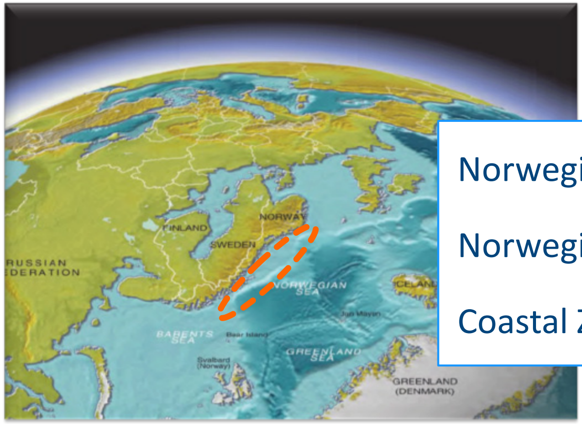


(Source: Fulton et al.; willow: Zero; seaweed: SINTEF and Danish Technological Institute)

(Handå et al., 2009, modified 2013)

Ethanol yield from cultivated kelp

Production potential in Norway?



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- 1.050.000 tons dry matter
- 630.000 tons carbohydrate
- **518.000 tons ethanol**

Seaweed – the marine biomass for the future

Thanks to

The Research Council of Norway (MacroBiomass)

SINTEF (Priority Project on Biobased economy)

The Research Council of Norway

Thank you!