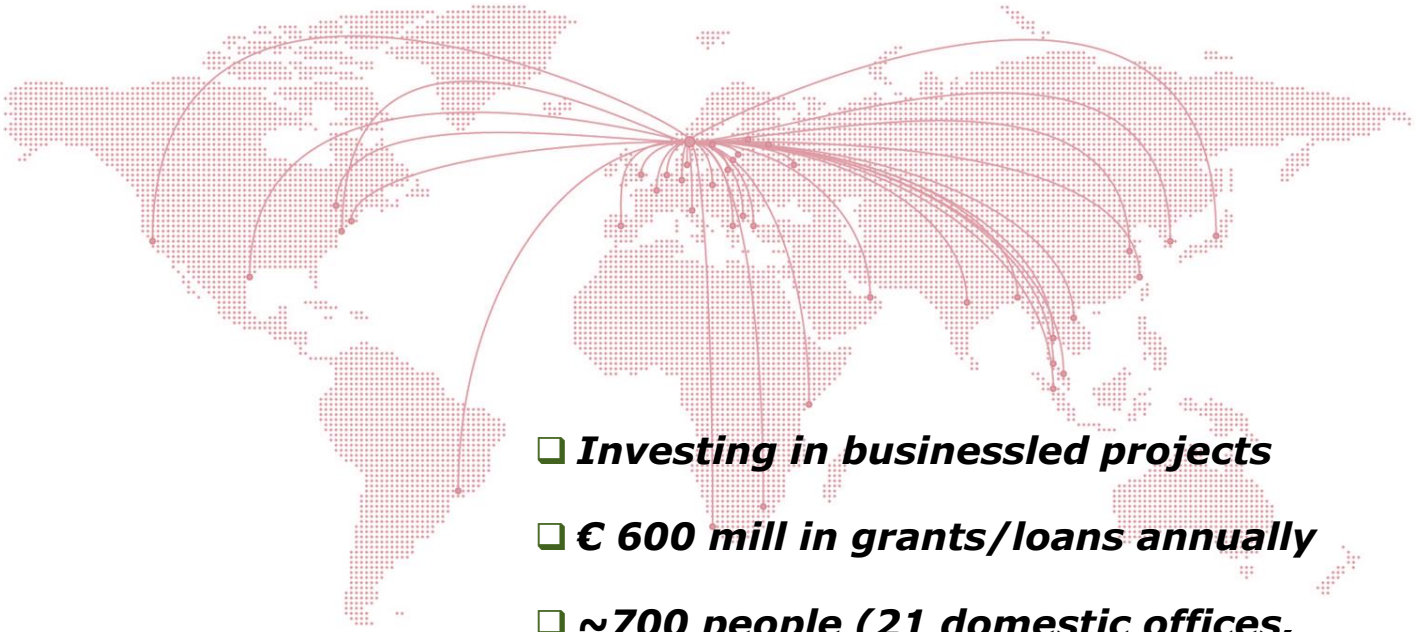
Innovasjon Norge

Biorefining of marine biomass

ERA-net Marine Biotechnology,
Brussels 13th October 2016

Ole Jørgen Marvik, PhD
Special Advisor Biobased Industries

The main Government agency for innovation and industry development



- ***Investing in businessled projects***
- ***€ 600 mill in grants/loans annually***
- ***~700 people (21 domestic offices, 38 offices in 31 countries)***

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Giving local ideas global opportunities

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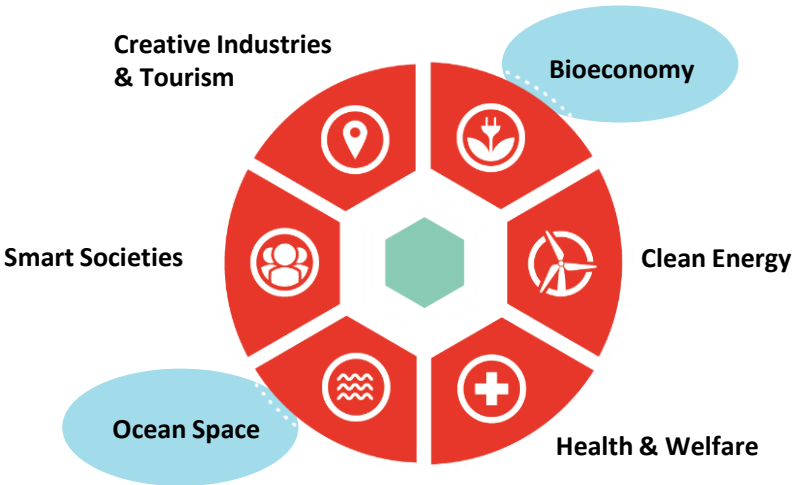
Nurturing a sustainable economy



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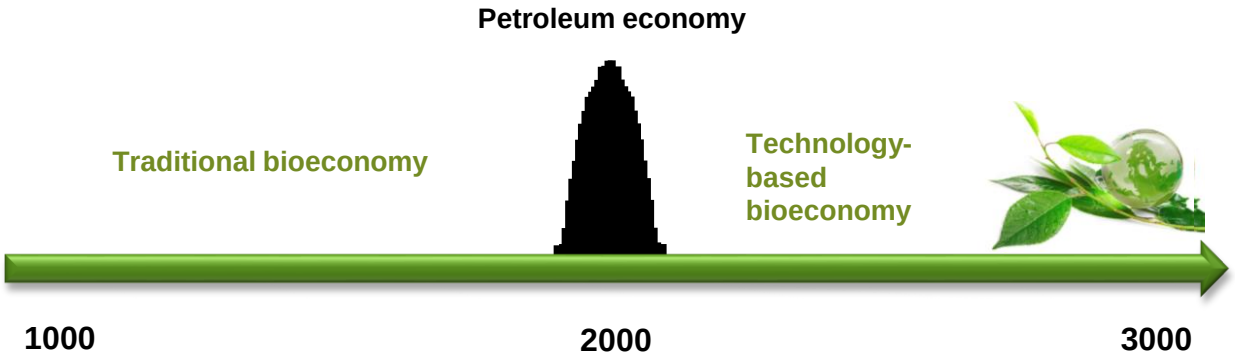
"What ever happens in this century, we will have to learn to live without fossil hydrocarbons."

Prof. David Goldstein, CalTech: "Out of Gas: The End of the Age of Oil", 2004



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Technology is the mother of change

The Stone Age did not end due to shortage of stone!

What about the Petroleum Age ???

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Turn of the tide ?

=

A 5 kg salmon:
45 USD

A barrel of crude:
46 USD

As of July 2016

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The blue bioeconomy

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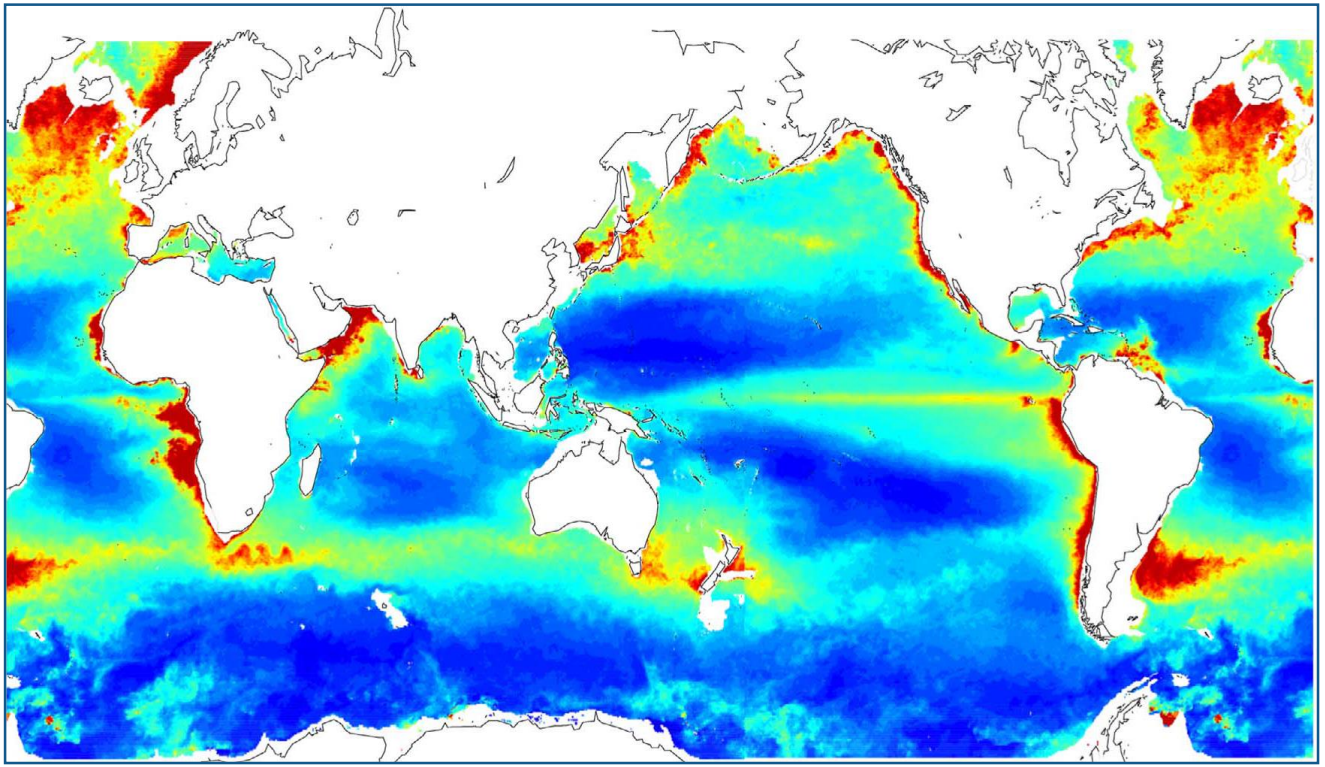
Marine primary production



1000 500 0 (mg C m2 d–1)

Source: Irigoien et al., 2014

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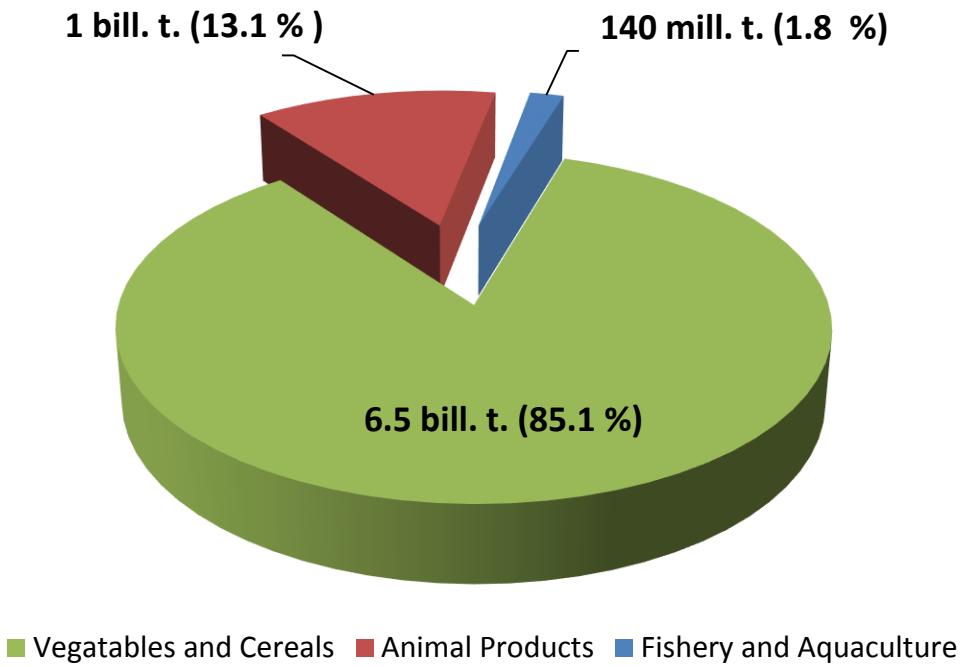
The global food production



Source. FAO stat 2008

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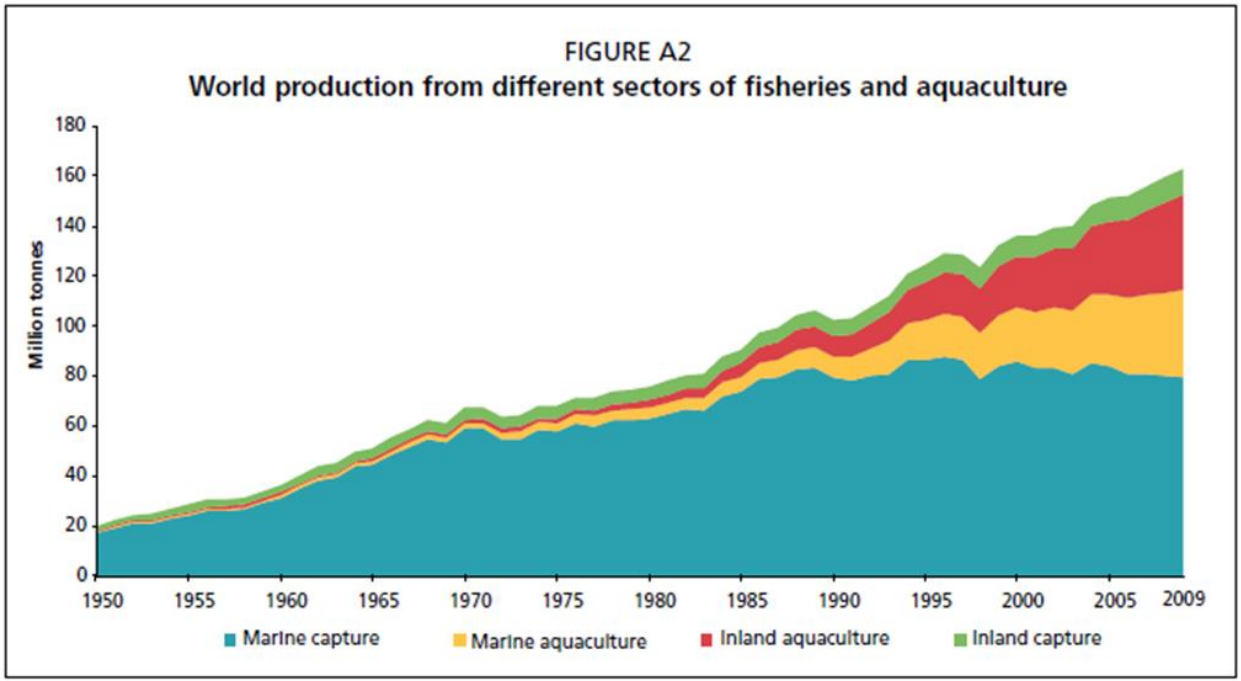
The global marine food production



FAO Fisheries and Aquaculture Department: Review of the state of world marine fishery resources 2011, ISSN 2070-7010

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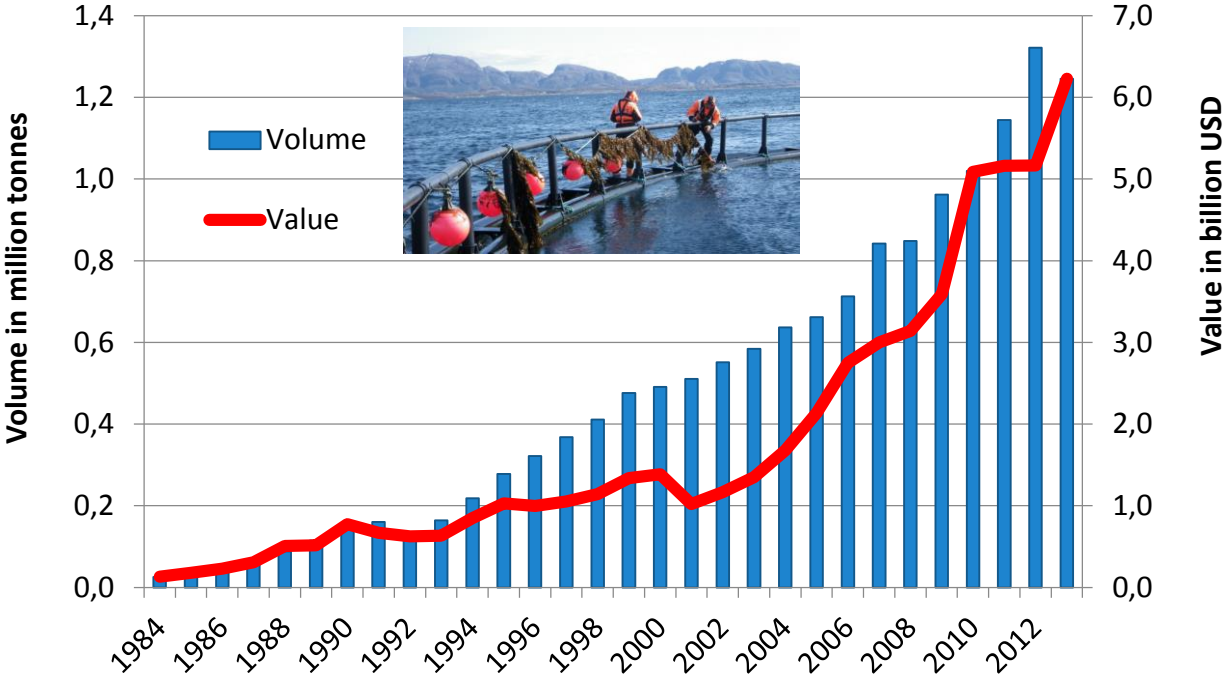
Norwegian aquaculture production



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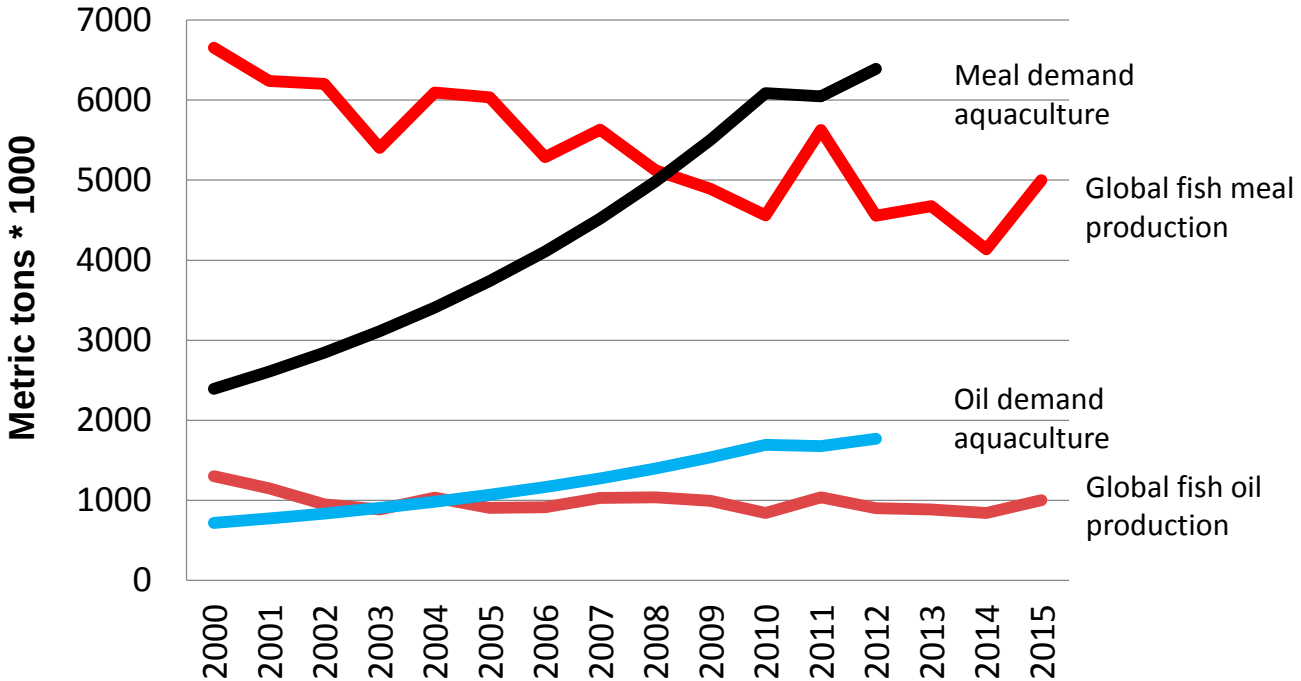
Feed ingredients demand vs production



Source: Norwegian Institute for Marine Research

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A 3-fold increase in salmon production ?

But from where do we source the 5 mill tons of feed?

OMEGA-3 LIPIDS

- ❑ **Anchoveta**
- ❑ **Lower trophical spieces (krill or Calanus)**
- ❑ **Microalgae**
- ❑ **GMO microbial production**
- ❑ **GMO plants (Camelina)**

PROTEIN

- ❑ **Fish meal**
- ❑ **Soy**
- ❑ **Yeast from cellulosic sugar**
- ❑ **Methylococcus from methane**

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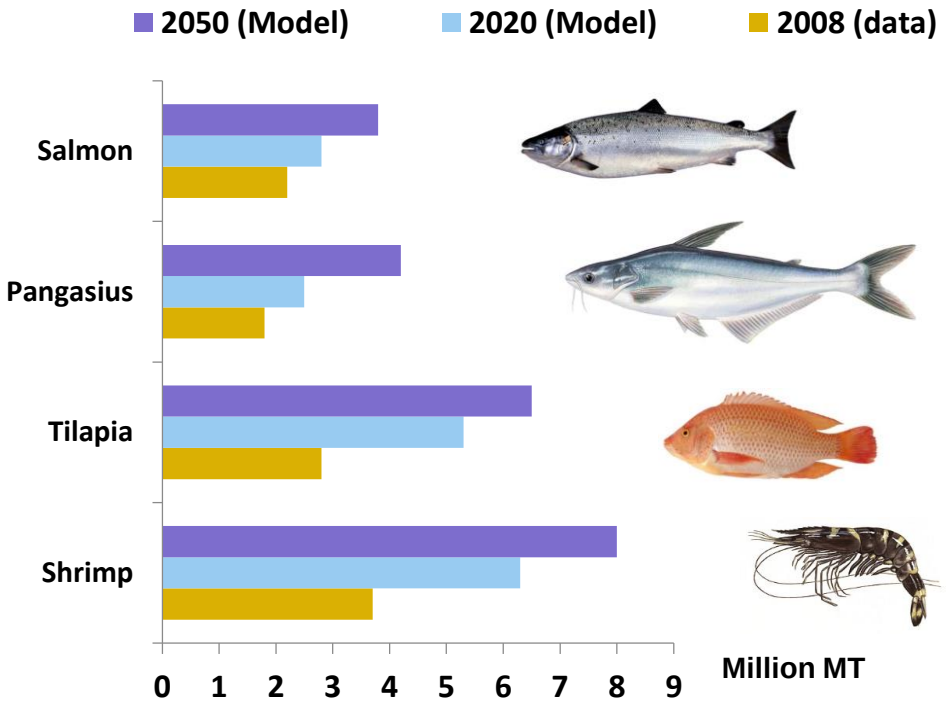
Aquaculture: Four major industrialized species



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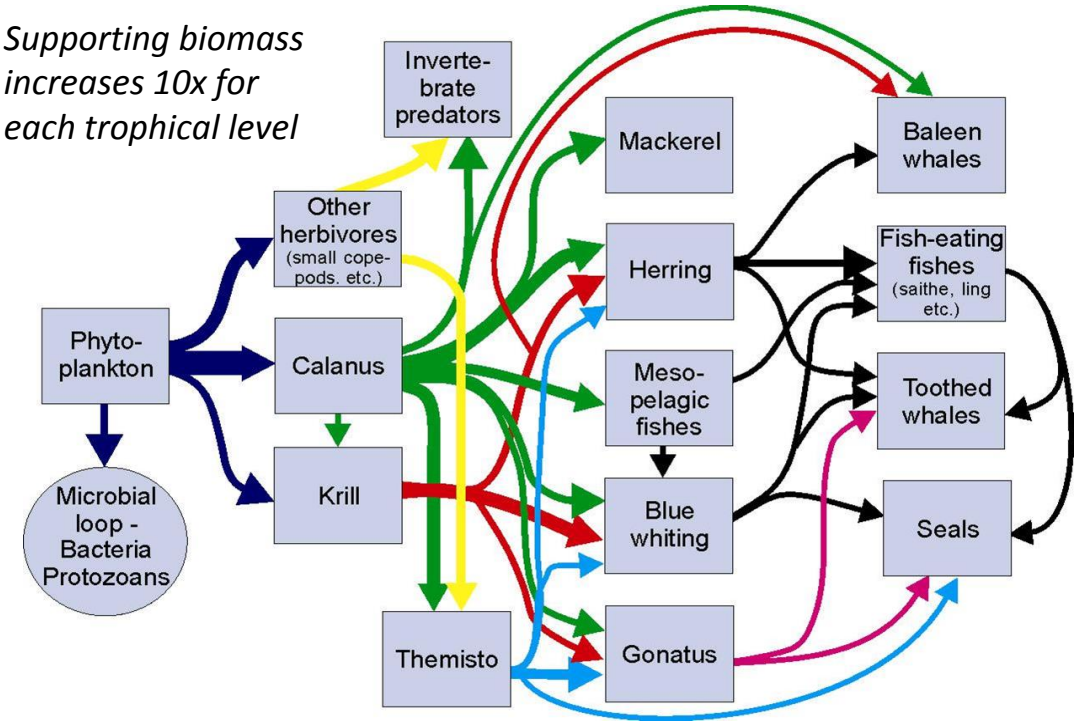
Managing the marine value chains

Supporting biomass increases 10x for each trophical level



Courtesy of Prof. Øystein Lie, NMBU

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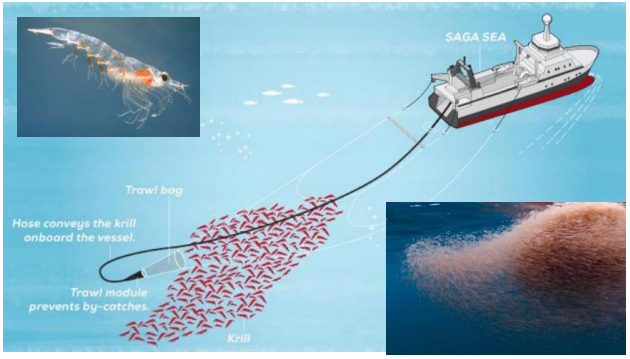
Krill – a large international resource



Antarctic quota 600.000 tons (few schooling species in North-Atlantic).

- Chitin component not exploited.
- DHA/EPA variable up to 20% of lipids.
- Some species high in wax esters.
- Rich in valuable phospholipids.

Difficult to process at sea:

- ✓ Dried meal taken on shore for extraction of phospholipids.
- ✓ NOK 1500,- per kg (120 GBP).

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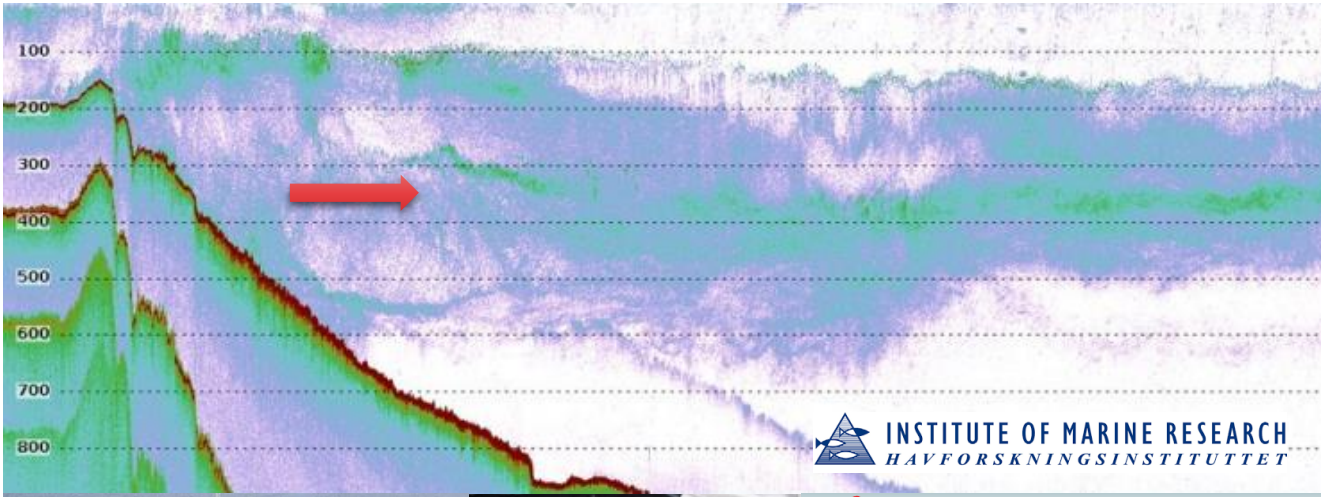
Mesopelagic fish – an unexploited resource



INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET

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Large mesopelagic fishes biomass and trophic efficiency in the open ocean

Xabier Irigoien[1], T.A. Klevjer[1], A. Røstad[1], U. Martinez[2], G. Boyra[2], J.L. Acuña[3], A. Bode[4], F. Echevarria[5], J.I. Gonzalez-Gordillo[5], S. Hernandez-Leon[6], S. Agusti[7,8], D.L. Aksnes[9], C.M. Duarte[7,8] & S. Kaartvedt[1]

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Mesopelagic fish – global opportunities

- Many potential species, mostly mycoptids, e.g. *lantern fish*
- Global biomass > **<u>10 billion tons</u>** *(Norw. Inst. Marine Research, 2014).*
- Harvesting 1% = 100 mill tons, i.e. equal to total current fisheries **!**

- Autolyse quickly and not well suited for direct consumption.
- Lipid content 20-60% of dry matter.
- **Enabling technology:**
  - ✓ Harvesting technologies adaped from krill
  - ✓ Novel refining technologies on board

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What else to harvest from the blue garden?

Kelps:

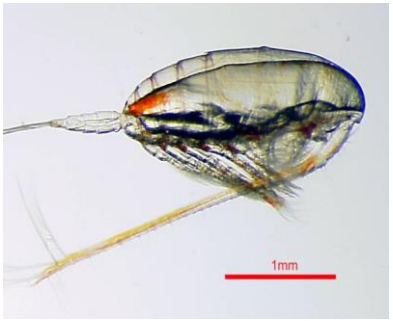
Laminaria hyperborea

FMC Biopolymer AS

Invertebrates:

Tunicates sp.

Tunichore AS



Zooplankton:

Calanus finmarchicus

Calanus AS

... and what new value chains can thus be created?

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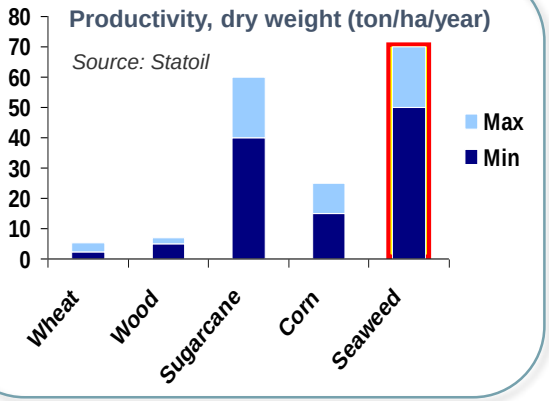
Kelps; a marine sugar platform

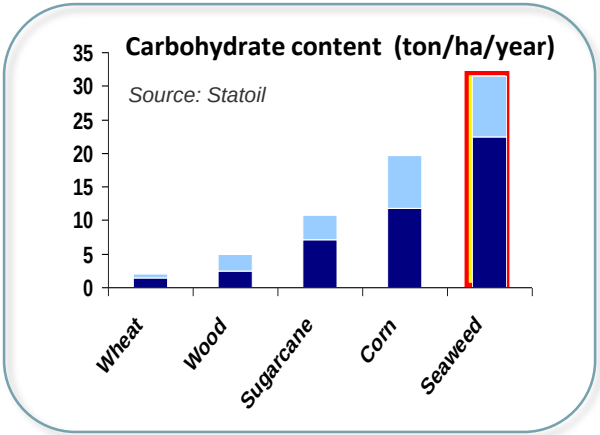
Mono-sugar

Starch

Cellulose

Alginate





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The sugar platform

Mono-sugar

Starch

Cellulose

Alginate

Enzymatic hydrolysis

Industrial fermentation

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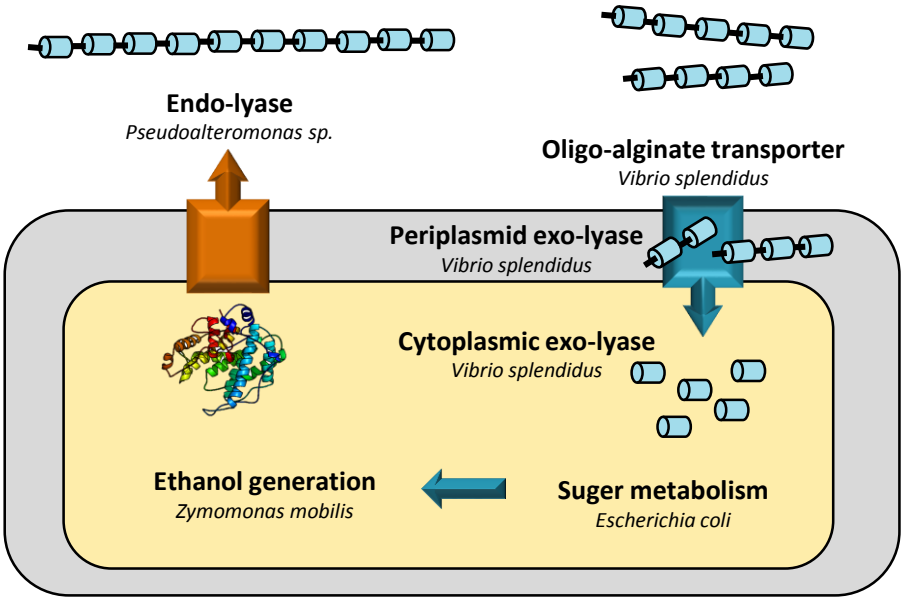
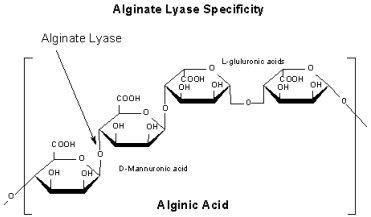
Consolidated bioprocessing of kelp





Consolidated bioprocessing:

- Enzyme production
- Feedstock degradation
- Feedstock metabolism
- Product formation

Ethanol yield:
4.7 % (v/v),… 3.9% after 48 h
80% of theoretical maximum

An engineered microbial platform for direct biofuel production from brown macroalgae. Wargacki et al, 2012. Science 335, 308-313 – ***Bioarchitecture Lab/Statoil***

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Tunicates – from problem to products

Tunicates from **Tunichore AS**, Bergen

Table 1: Composition analysis (g/100g)

Component	Raw biomass	Inner organs	Tunic
Ash	40.9+0.1	18.9+0.1	6.5+1.4
Protein*	52.8+0.8	73.5+2.1	37.4+0.3
Cellulose*	18.7+0.2	3.0+0.3	44.8+0.9
Lipids*	1.2+0.0	2.8+0.1	1.3+0.1

Lignin-free cellulose !

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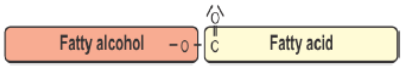
Zooplankton – *Calanus finmarchicus*

- Copopod in Northern Atlantic.
- 150-300 mill tons in the Nordic region (20x all fish).
- New technology increases catchability.
- High content of antioxidants (astaxanthin).
- Lipids mainly as wax esters (WE).
  - Potential source of PUFA (30-40% of total WE)
  - WE difficult to digest by Atlantic salmon
- Potential to increase bioavailibility by in vitro enzymatic hydrolysis?



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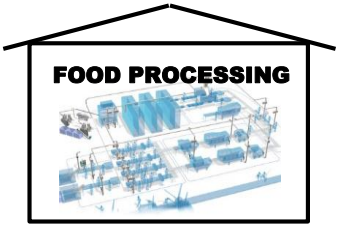
Integrated biorefining

1,3 mill MT

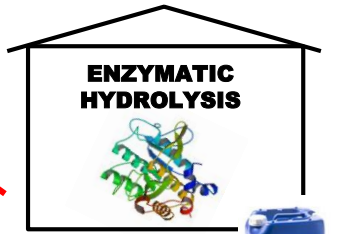
50%



50%

~~waste~~

Co-products



e.g. proteases

Protein

Lipid

Bone

- PROTEIN SUPPLEMENTS
- BIOACTIVE PEPTIDES
- COLLAGEN
- PEPTONES
- LIPID SUPPLEMENTS
- MODIFIED LIPIDS
- PHOSPHOSLIPIDS
- GLUCOSAMINE
- CHONDROITIN
- MARINE MINERALS
- FLAVOURS

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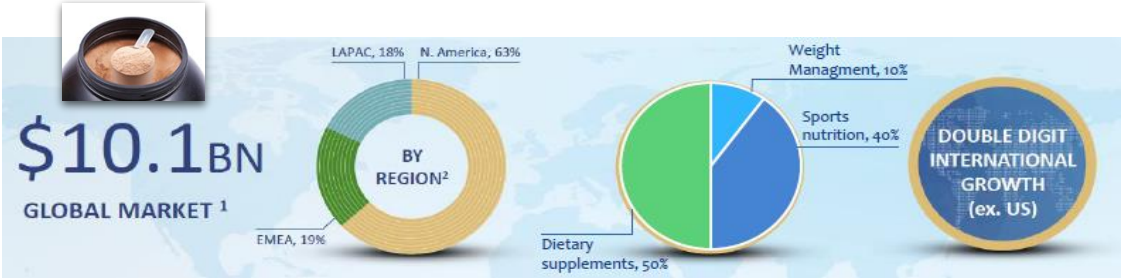
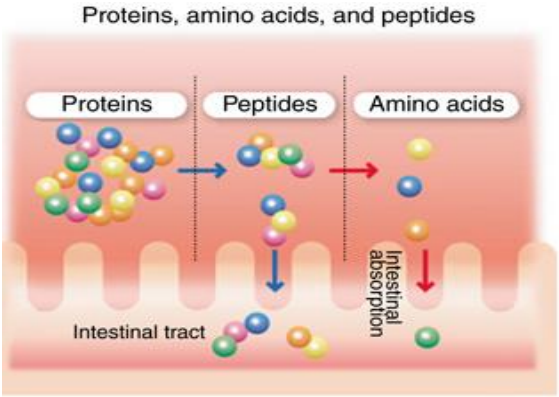
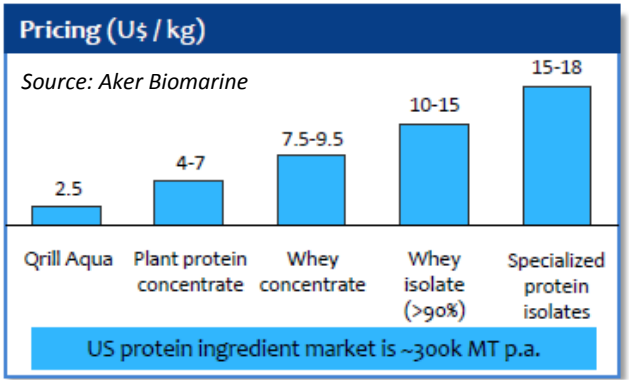
Reaching out to high end markets







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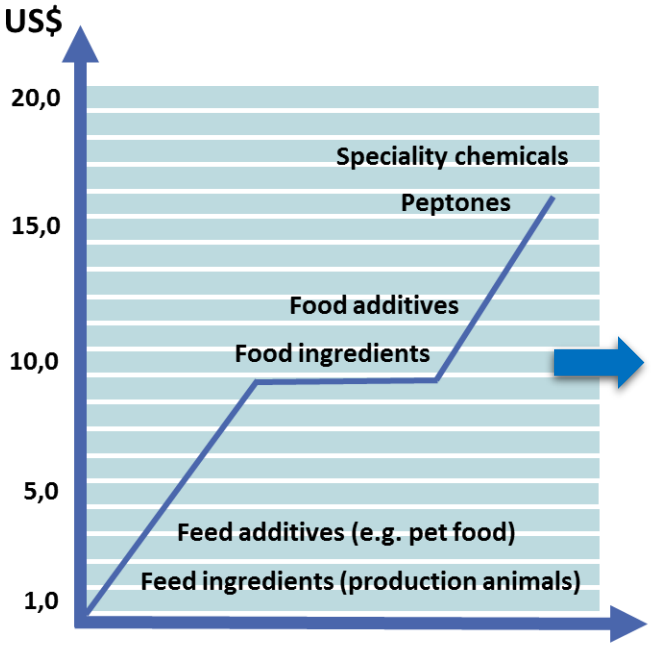
Barriers to the human market



«Fishy» taste

Caused by the post-mortem production of trimethylamine

Bitterness

Undesirable peptide spectrum and molecular configurations

Rancid taste and smell

Unsaturated lipids common to fish, are easily oxidized

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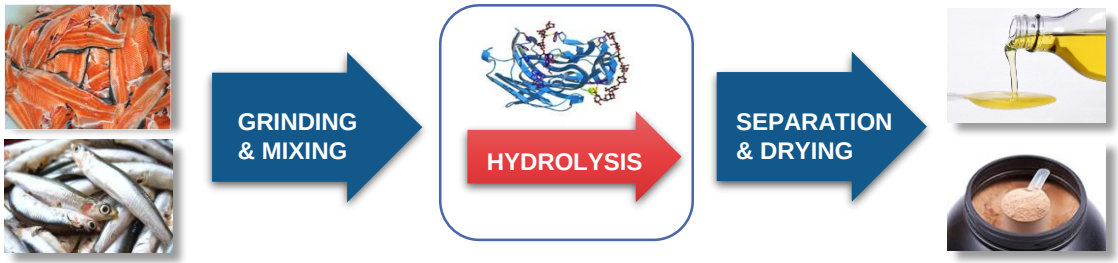
Key features and profitability



- **Continous flow rather than batch, increases reproducibility.**
- Avoid mechanical stirring creating emulsions where oil and protein are difficult to separate.
- Closed reactors to reduce oxidation of lipids.
- **Gentle enzymatic degradation retains nutritional value of proteins.**
- Enzyme-mix optimised for the feedstock in question, improving functional and sensoric properties.
- Enzymes approved for human grade processes.

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Norwegian national facility for marine process scale-up

BIOTEP – at Kaldfjorden, close toTromsø

www.biotep.no

- A **open access** pilot facility for processing of marine co-products.
- Inaugurated in 2013 by the Minister for Coast and Fisheries.
- State of the art equipment for scale-up, optimization and test production, including a full process line for enzymatic hydrolysis.
- Operated by Nofima

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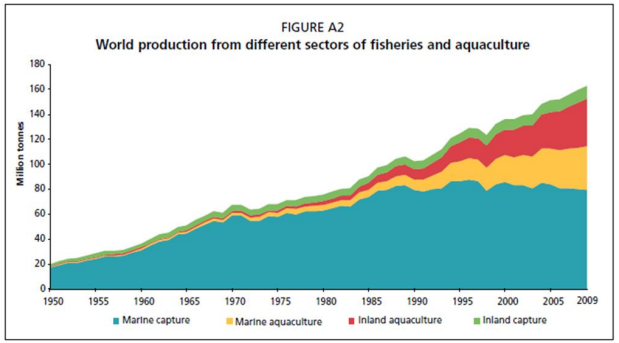
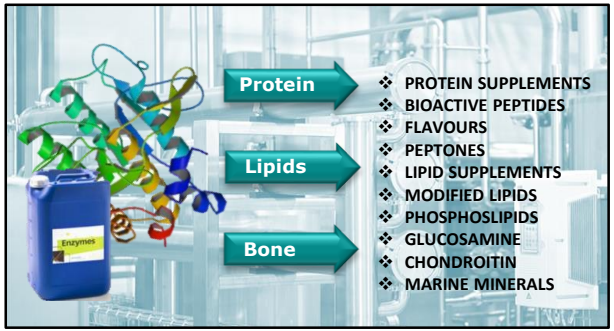
Capturing the full marine potential



Solve the feed problem to expand aquaculture

Harvest sustainably at lower trophical levels



Reduce discharge and utilize the whole fish

Make co-products of superior quality and value

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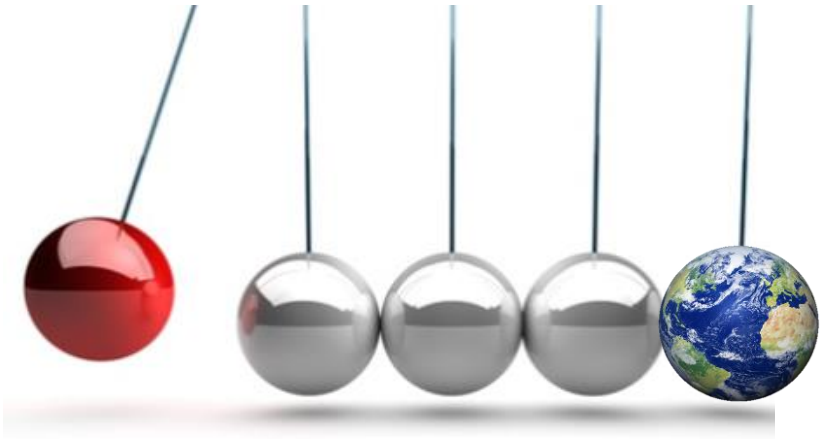
Biotechnology…



…sets great things in motion