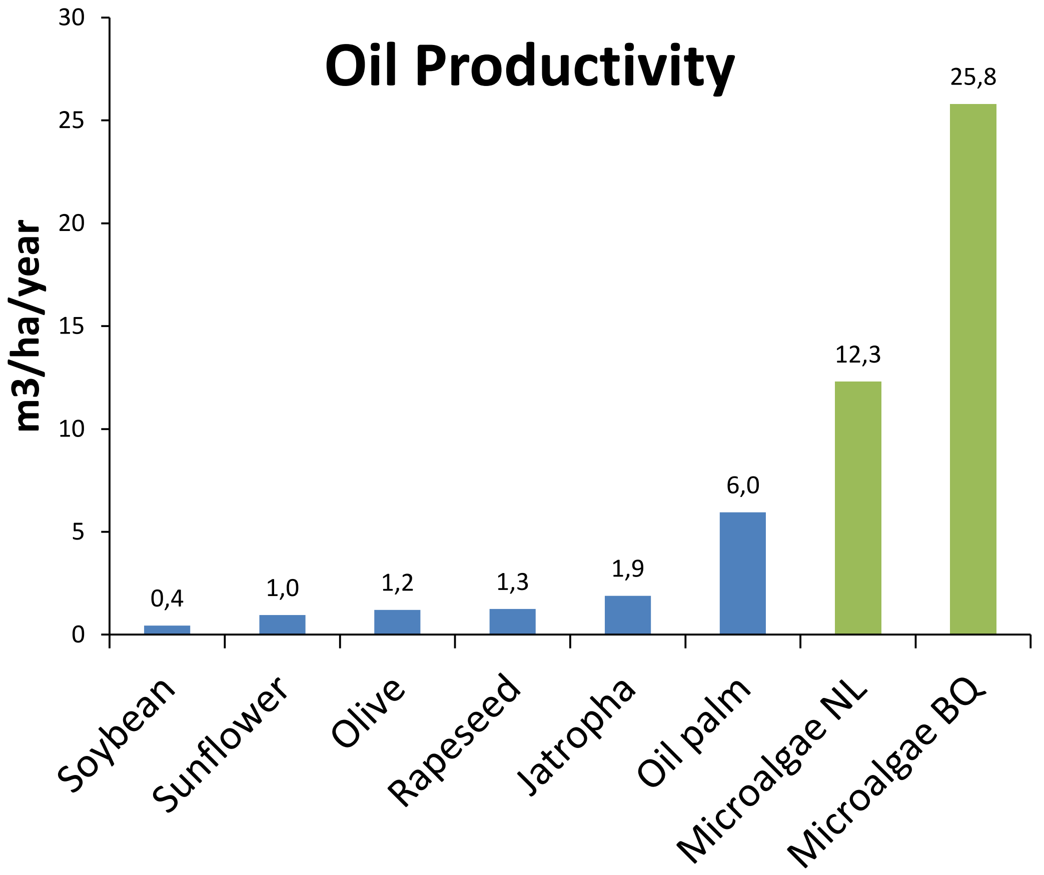
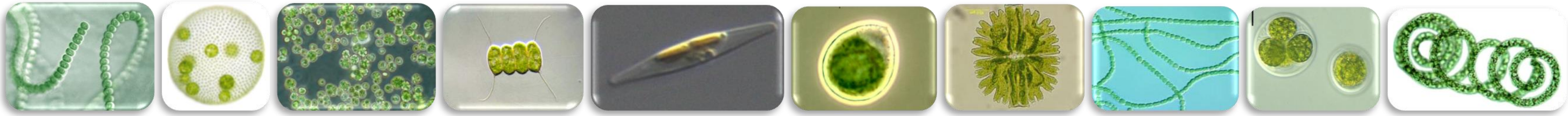
# The National Algaepilot Mongstad: production of microalgae for food and feed

Dorinde Kleinegris, Hanna Böpple, Pia Steinrücken,
Svein Rune Erga, Hans Kleivdal

# Why microalgae?

- High diversity → many products
- High areal productivity
- $CO_2$ mitigation
- No arable land
- Low water use
- Fresh water, seawater and wastewater
- Steer metabolism towards product of interest



# Main components

## Microalgae

### Lipids

**Storage lipids**

Mainly TAGs
Up to 50% of DW

**Membrane lipids**

Different lipid classes (phospholipids, galactolipids,….)
Up to 40% of total lipids are PUFA

### Carbo-hydrates

Storage products
A-(1,4)-glucans
B-(1,3)-glucans
Fructans
Sugars, glycerol

Exopoly-saccharides: galactose, fucose, rhamnose, arabinose, xylose, glucose

### Proteins

High content, up to 50% of DW

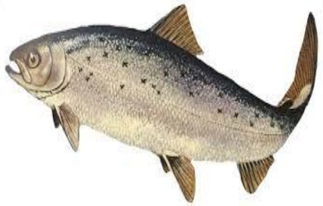
All 20 amino acids

### Other valuable compounds

Pigments
Antioxidants
Vitamins
Anti
- Fungal
- Microbial
- Viral

Toxins
Sterols
MAAs







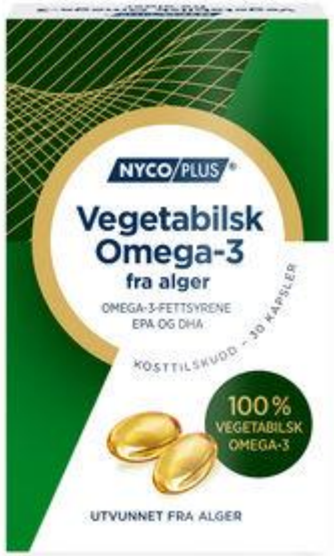






# Some microalgae products currently available in Norway






# Still a gap to bridge for commodities from microalgae

NORCE

**Commercial production challenges:**

- Product costs
- Scale
- Production chain analysis
- Market development

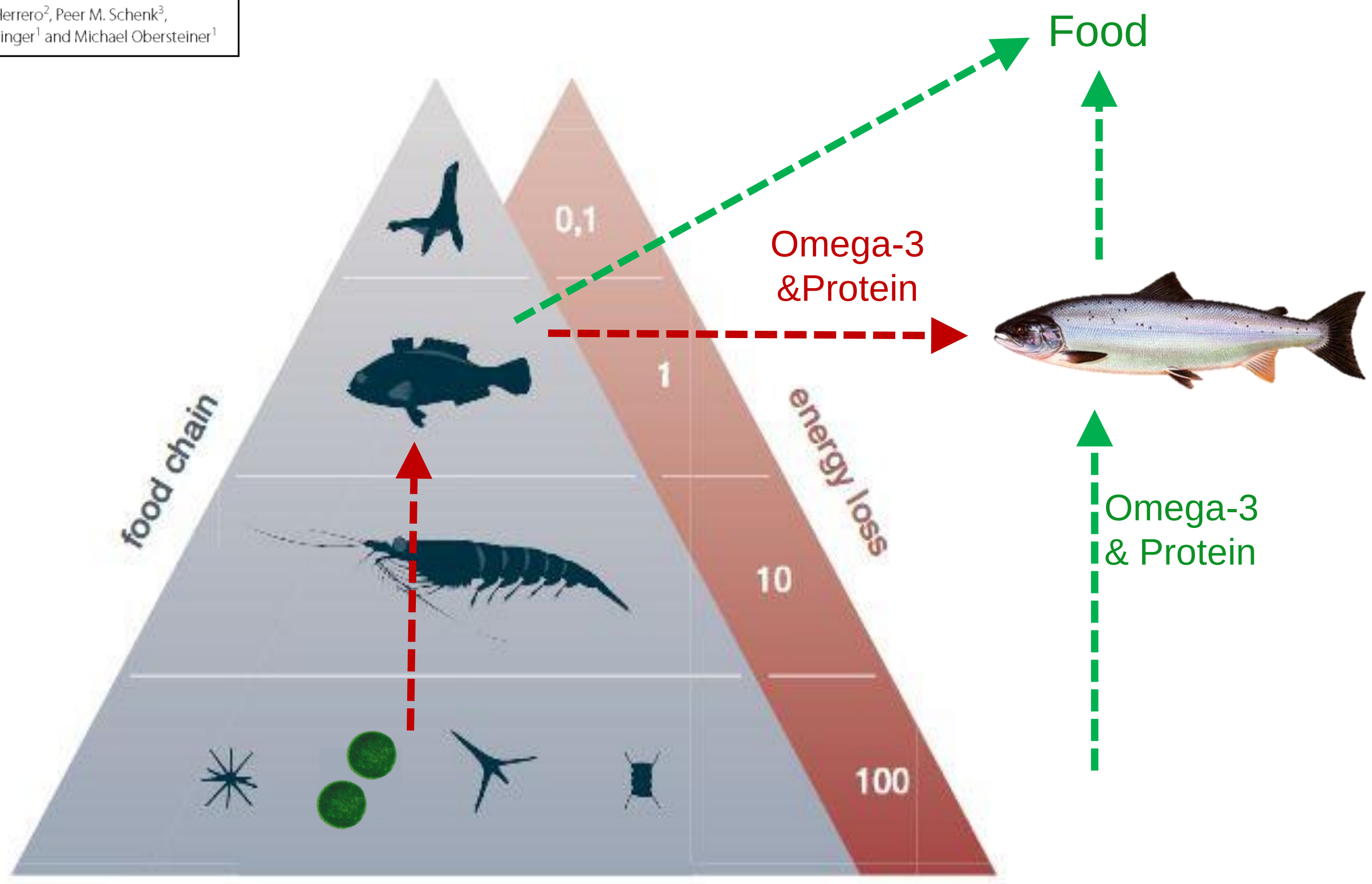
Walsh *et al. Carbon Balance Manage* (2015) 10:26
DOI 10.1186/s13021-015-0040-7

Carbon Balance and Management
a SpringerOpen Journal

RESEARCH Open Access

New feed sources key to ambitious climate targets

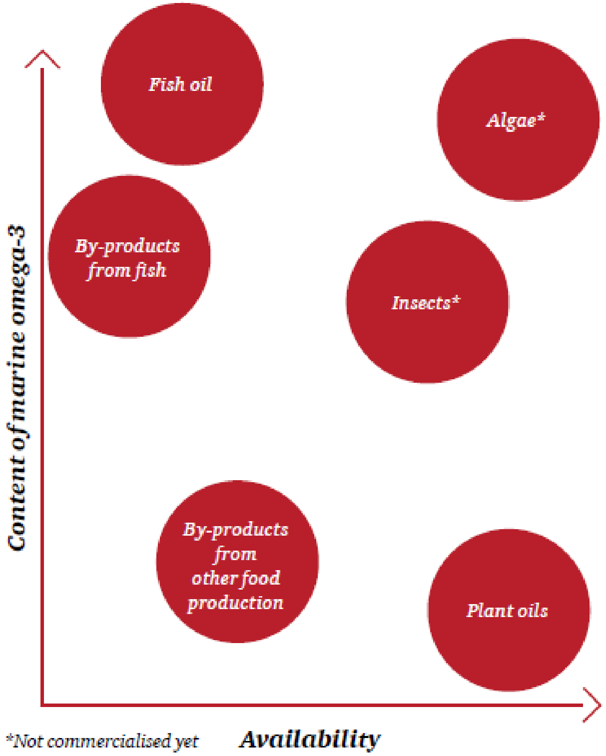
Brian J. Walsh[1*], Felicjan Rydzak[1], Amanda Palazzo[1], Florian Kraxner[1], Mario Herrero[2], Peer M. Schenk[3], Philippe Ciais[4], Ivan A. Janssens[5], Josep Peñuelas[6,7], Anneliese Niederl-Schmidinger[1] and Michael Obersteiner[1]




- Directly utilize the source of nutrients from the bottom of the chain

# Lack of available feed ingredients will be an important challenge in the long run

The availability of marine feed ingredients will be a critical issue only a couple of years from now. The availability of traditional fish meal and oil does not increase, while global aquaculture continues to grow.




*Not commercialised yet

The global supply of *fish meal and oil* has been static for decades,[74] and the share used for fish feed has increased rapidly. Finding new sources is urgent to ensure a high share of marine omega-3 in the future.

Using by-products is good from a sustainability perspective. *Fish by-products* is particularly positive as it supplements the marine content in the feed. 340,000 tonnes of whitefish by-products are thrown overboard annually in Norway.[75] Still, the availability will not be sufficient in the long run as it is a scarce resources.

Shifting from fish oil to *plant oil* has been the answer so far. Salmon now eat feed with a high share of plant based ingredients - plants which are produced on land which otherwise could have been used for for human consumption. In addition, the marine omega-3 content is low.

*Insects* are often mentioned as a future source of proteins for both humans and animals. If produced in a commercial scale, the availability will probably be good, and the price low. Insects may also be a potential source of omega-3.[76]

*Algae*, specifically microalgae, may be able to offer the best from both the animal and plant world. The algae may grow fast, and can be produced commercially on a large scale, and may also offer the desired marine oils the salmon is known and appreciated for.

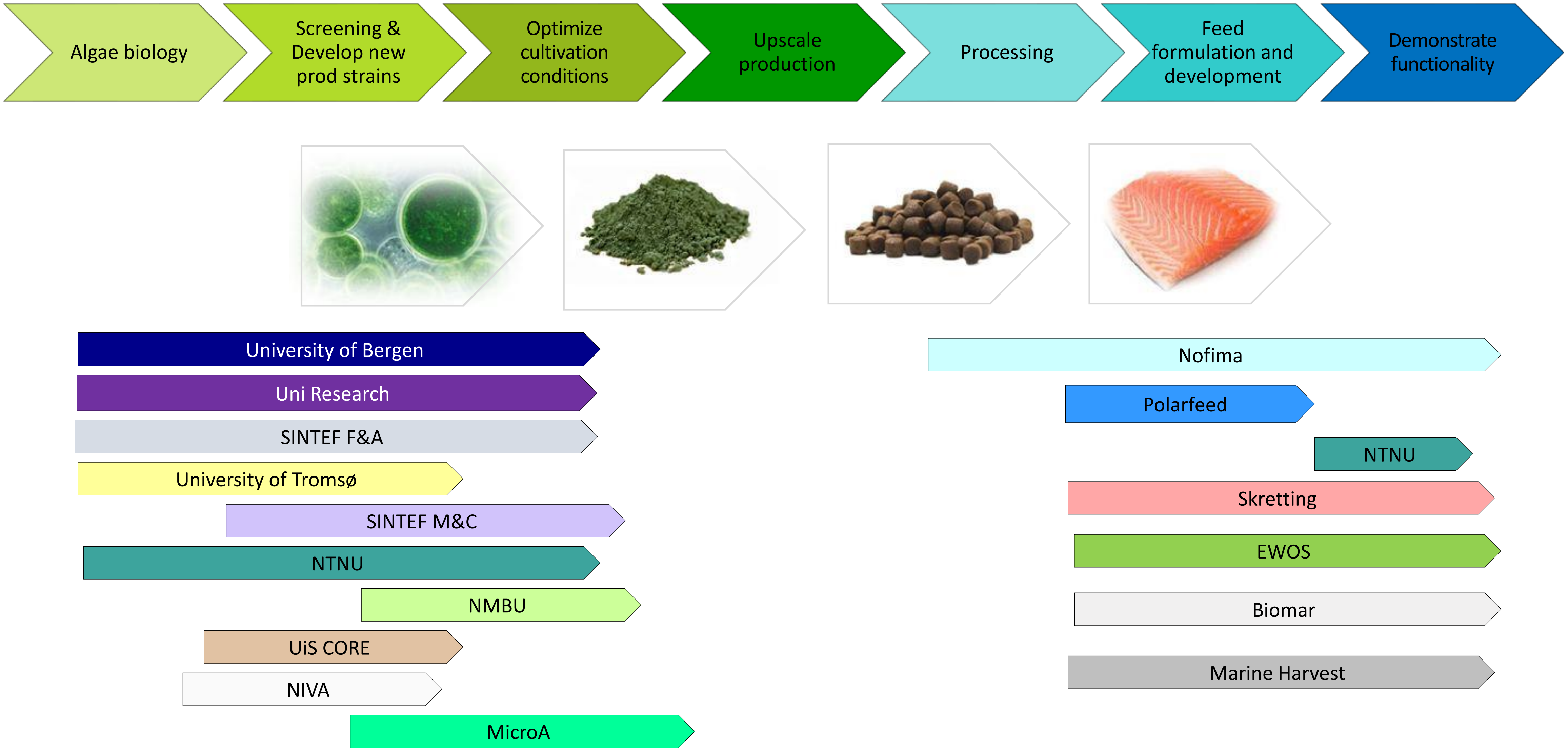
**55.6%** *of leaders in the industry* ***believe algae will be the most important ingredient*** *in salmon feed in the future.*

***PwC's Point of View:***
After solving the short term issues regarding lice and lice treatment, the next big challenge to overcome is where and how to find sustainable feed ingredients with the right nutritional content for salmon.

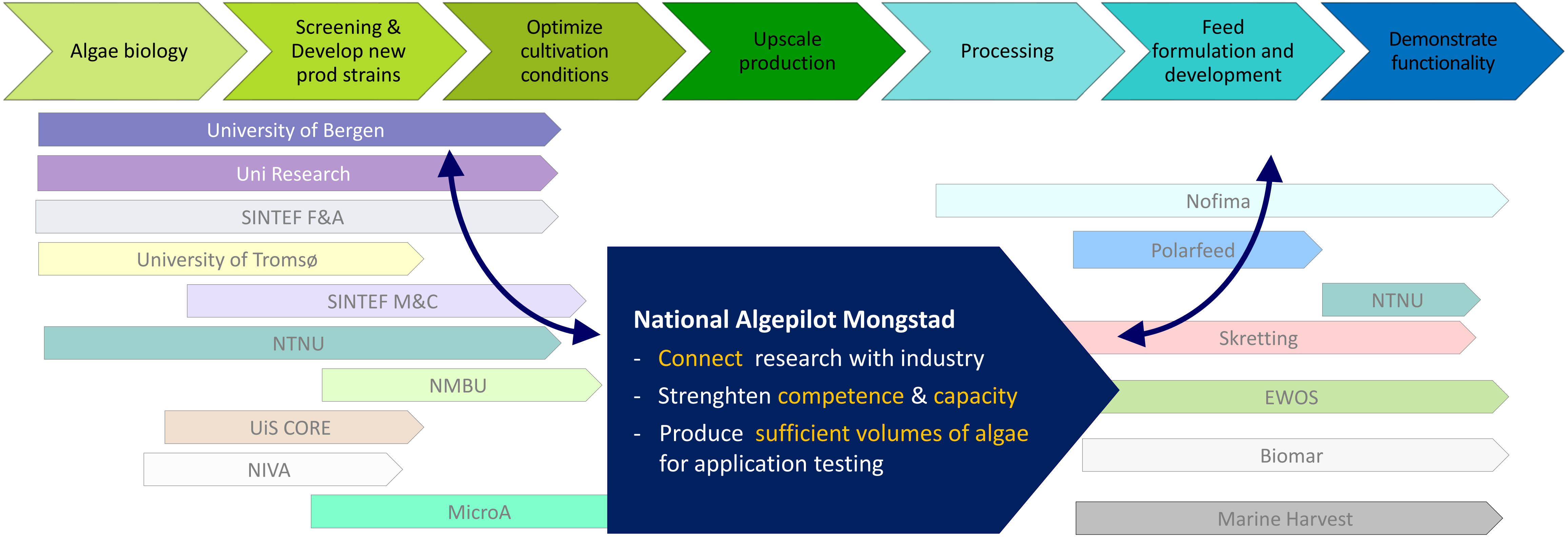
We believe that the salmon feed in 2050 will still have a high share of plant based ingredients, but with a significant share of algae and a small share of by-products. The share of traditional fish oil and meal will continue to fall.

***Sustainable growth towards 2050***
PwC Seafood Barometer 2017

# Roadmap for microalgae based aquafeed (2013)



# Roadmap for microalgae based aquafeed (2013)



# National Algaepilot Mongstad

## National platform for the industrialization of microalgae

- Owned by UiB
- Managed by UiB, NORCE and CO2BIO
- Build in 2016
- Operational since 2017
- Nextdoor to Equinor refinery and TCM

Financed by:

| | |
|---|---|
| University of Bergen | 6 mNOK |
| Seafood Research Fund | 3 mNOK |
| Government | 6 mNOK |
| Hordaland County | 2 mNOK |
| Municipality councils | 1 mMOK |
| | 18 mNOK |

# We develop the full microalgae production chain:

## from bioprospecting to process optimization and biomass production at pilot scale

Photo: Thor Brødreskift

…to development of new valuable products from microalgae

# Microalgae team @NORCE + UiB

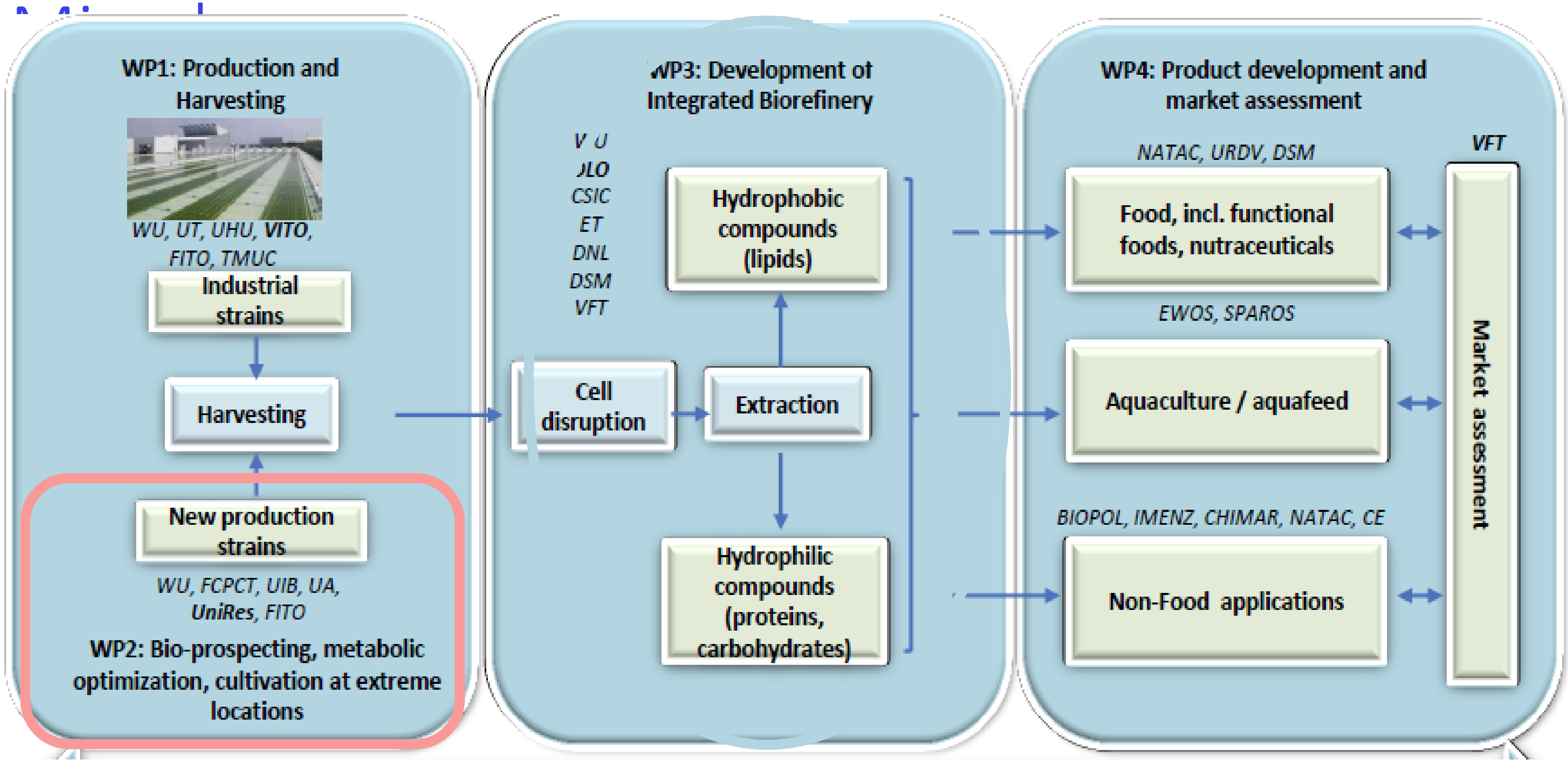
## CO2FOOD

## Algae2Future

## MIRACLES
SPECIALTIES FROM ALGAE

## Waste2Use

## IFishIENCI




NORCE

MIRACLES
SPECIALTIES FROM ALGAE

Aquaculture feed

Food & Nutraceuticals

Non-food specialties

# Bioprospecting + strain selection – Nordic climate

## Search for: strains with high EPA/DHA content.

## Assumption: Microalgae from northern high latitudes are expected promising candidates, as low growth temperatures can increase fatty acid unsaturation.

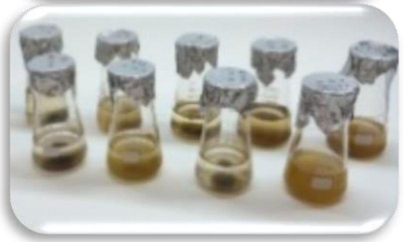
**Sampling**

58 events

**Isolation**

110 plates

**Cultivation**



149 clonal cultures

**Screening**

30 strains:

- Growth
- Fatty acids

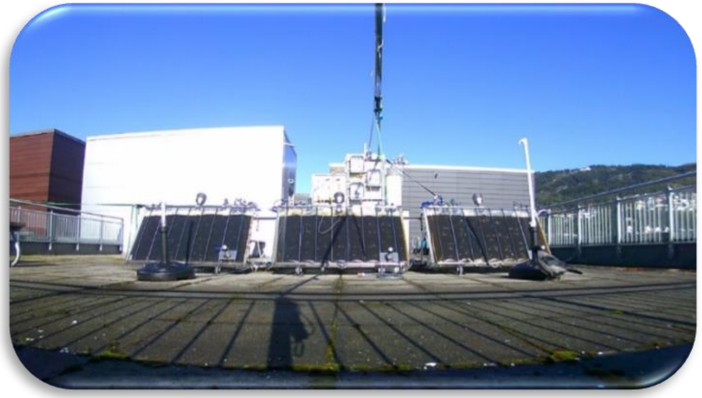
**Selection**

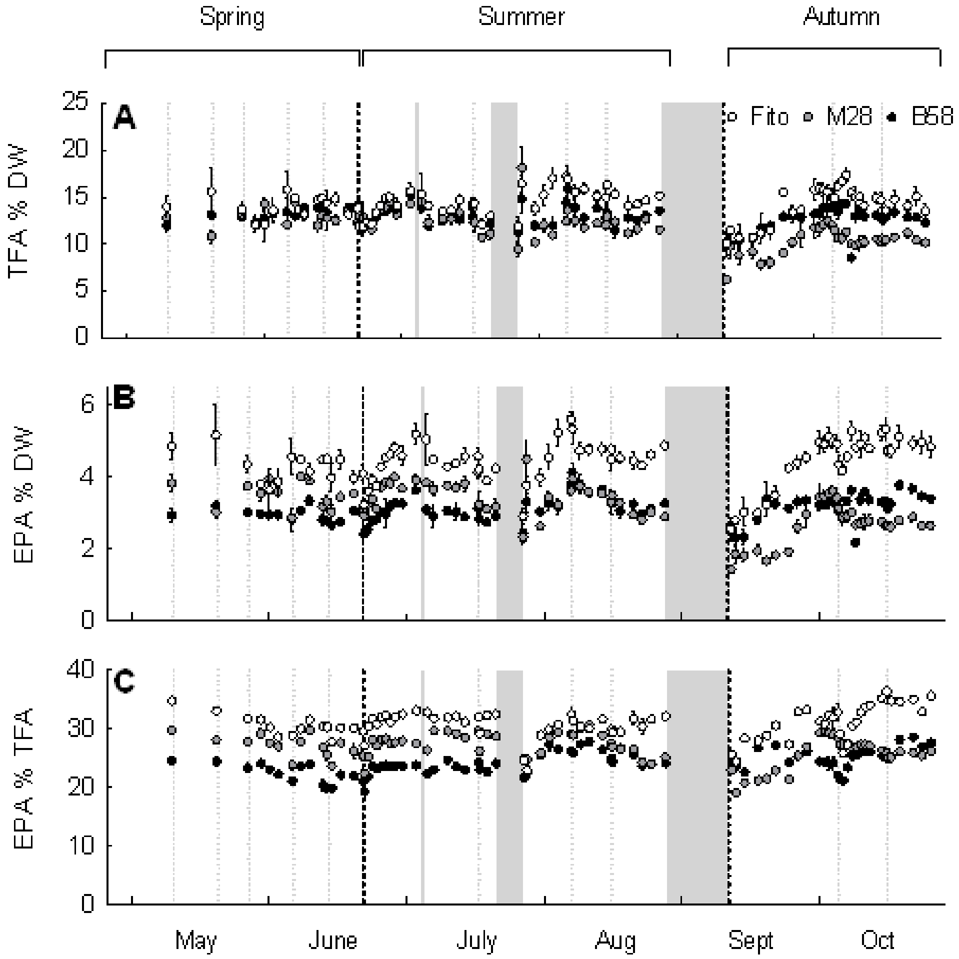
Promising strains:
growth rates > 0.7 $d^{-1}$
EPA/DHA >3% DW
→ 8 selected for further characterization

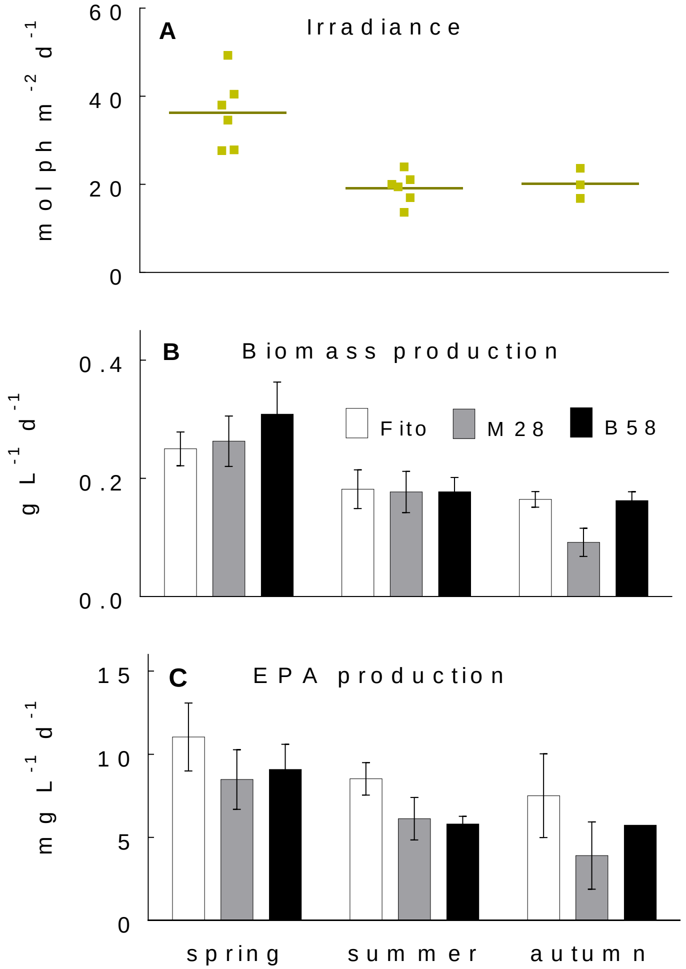
# Bioprospecting + strain selection – Nordic climate

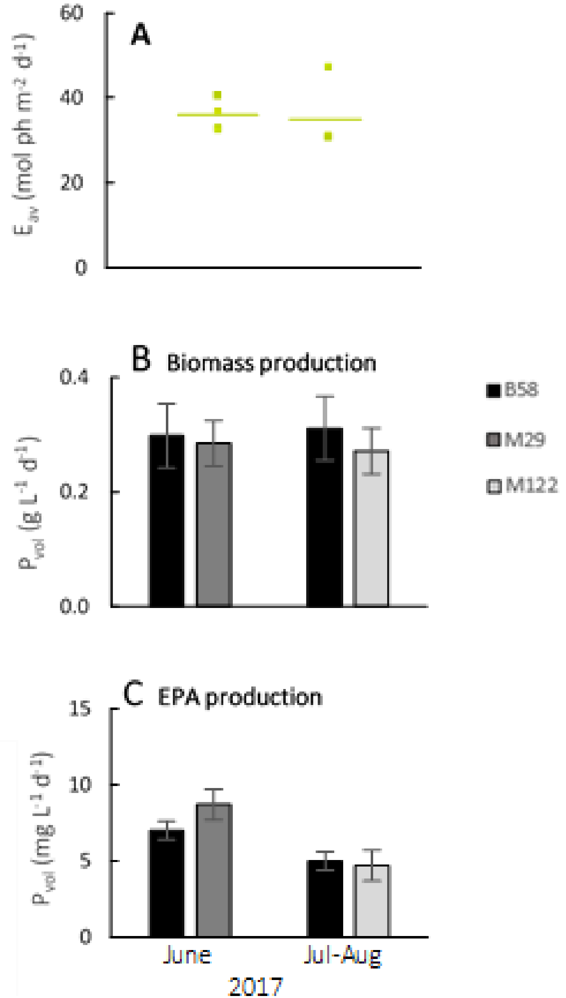
## Comparison under Nordic outdoor conditions in flat-panel PBRs

## Compared vs. commercial *Phaeodactylum* reference strain

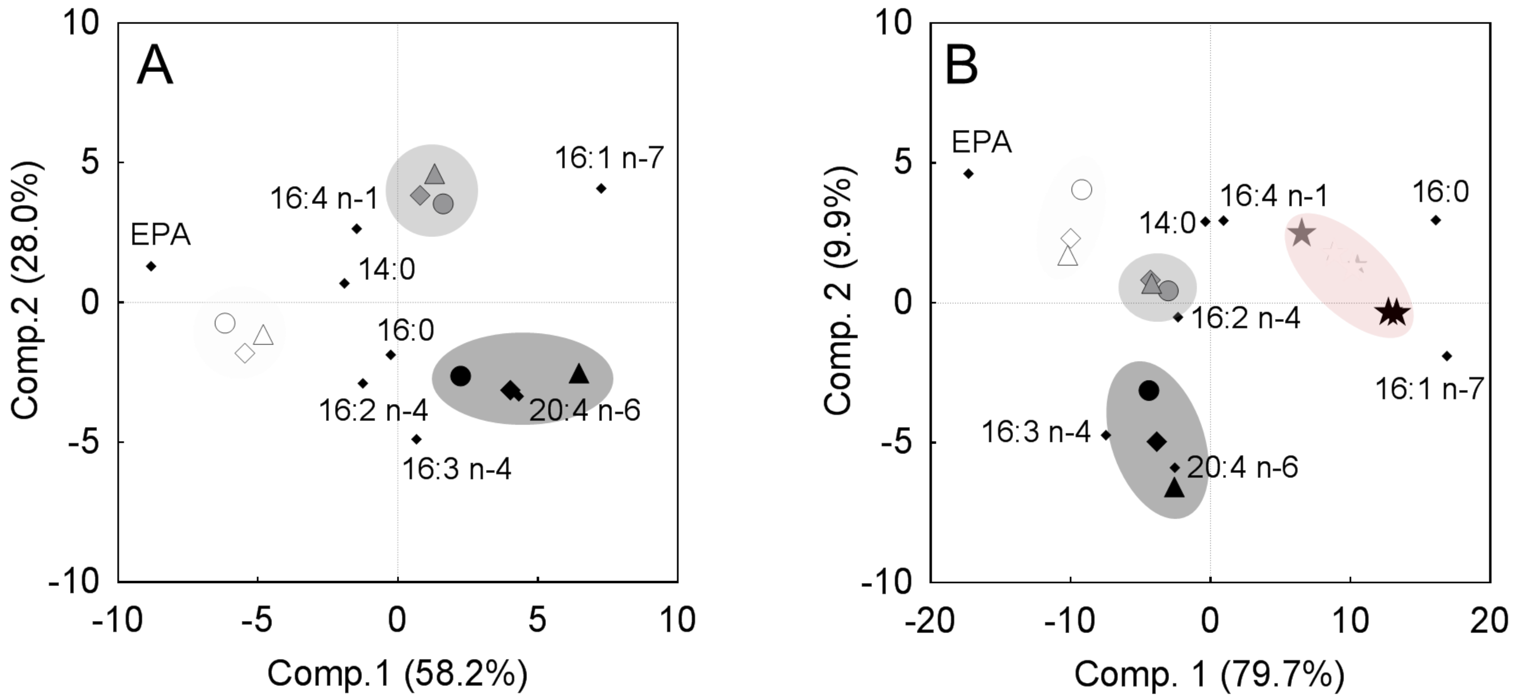




# Bioprospecting + strain selection – Nordic climate




A principal component analysis (PCA) of the average seasonal fatty acid compositions (%TFA) revealed strain-specific fatty acid profiles and only little influence of the season on the fatty acid composition.

However, adding fatty acid data from laboratory experiments to the PCA, revealed more significant differences between outdoor- and laboratory-grown cultures than between strains.

# Microalgae show great potential as functional ingredients in aquaculture feeds

EWOS® Cargill sparos I&D nutrition in aquaculture

NORCE

Experiments:

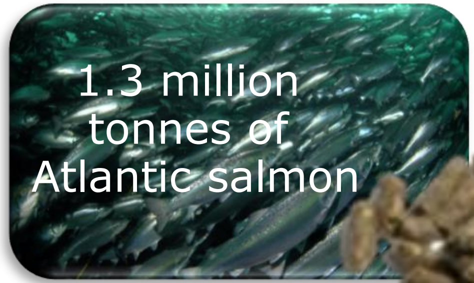
- *Nannochloropsis* and *Phaeodactylum* (whole cells, disrupted, residual biomass, oil)
- Diets with 1 – 8 % inclusion rates
- Tested on: salmon, gilthead seabream, senegalese sole

Demonstrated benefits on:

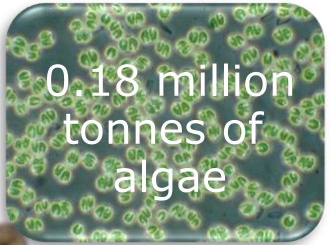
- **Animal welfare** (stress resistance, immunity, improved survival of larvae)
- **Consumer quality traits** (more vivid and typical external pigmentation)
- **Reduce reliance on finite marine-harvested resources** (e.g. replacement of fish meal (80%) and fish oil (30%) )

# Scale - Salmon as example

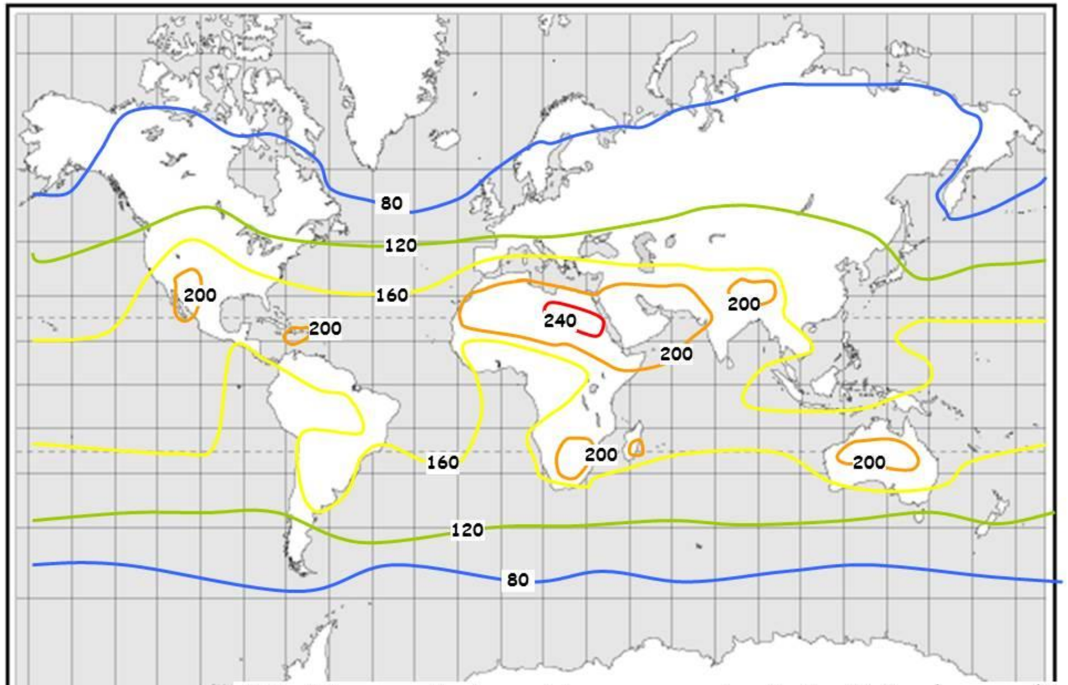
## Objective: replace 10% of fish meal with algae





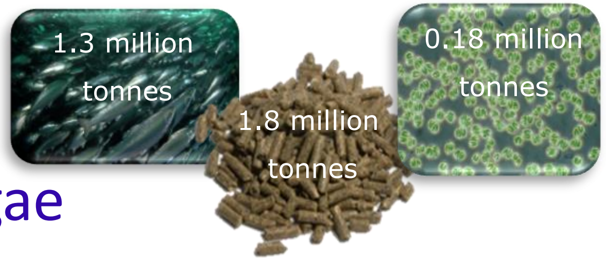



*Without algae* *With algae*




World map of algae biomass productivity (t $ha^{-1}$ $year^{-1}$)
(at 5% photosynthetic efficiency and 20 MJ $kg^{-1}$ dry biomass)
Source: Prof. Mario Tredici (Italy)

# Scale - Salmon as example



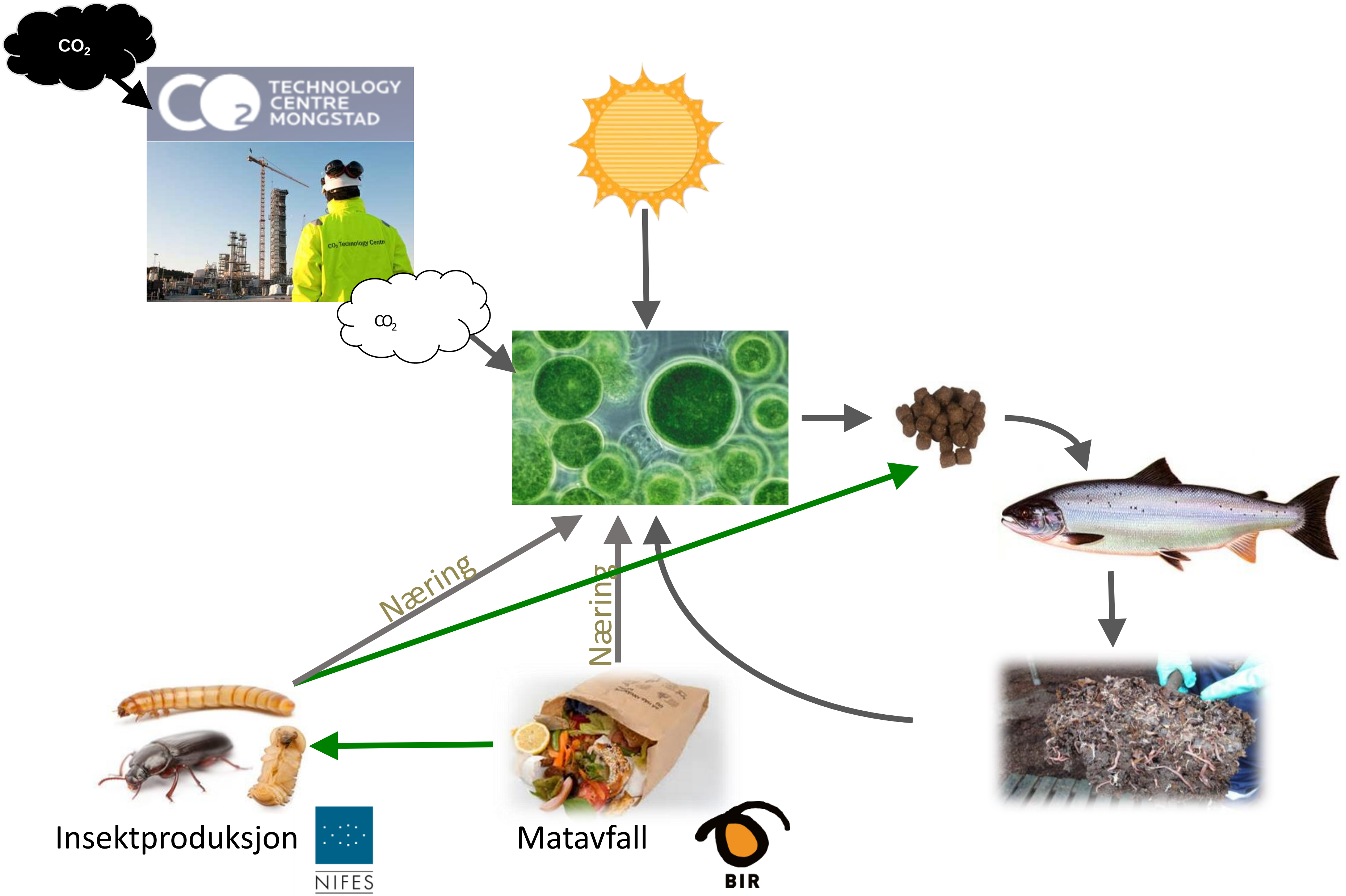

Objective: replace 10% of fish meal with algae

- Nutrients needed:
  - 293 400 tons $CO_2$
  - 14 670 ton N
  - 1 630 ton P

- TCM captures 100 000 ton $CO_2$ per year
- Yara produces in Norway alone 2,7 million ton NPK yearly

  BUT
- There are other sources as well....

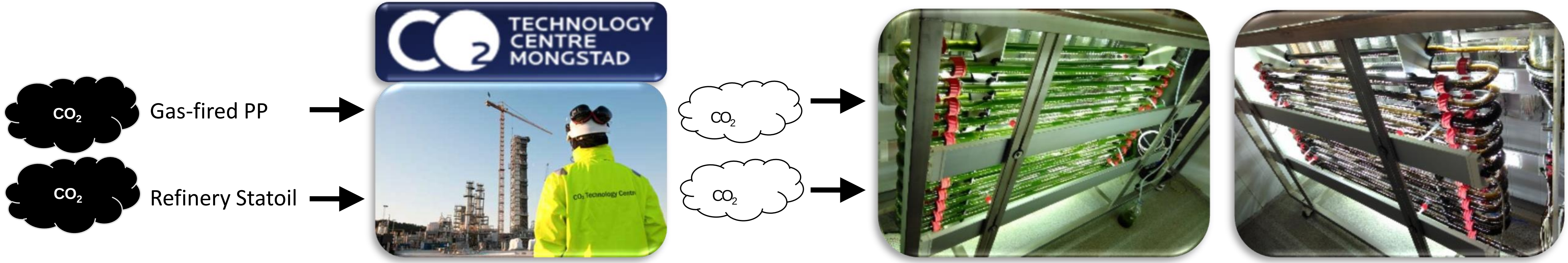
# Industrial symbiosis for development of new value chains



# Evaluation of different $CO_2$ sources for microalgae production

## Tested in 25L LGEM tubular PBRs:

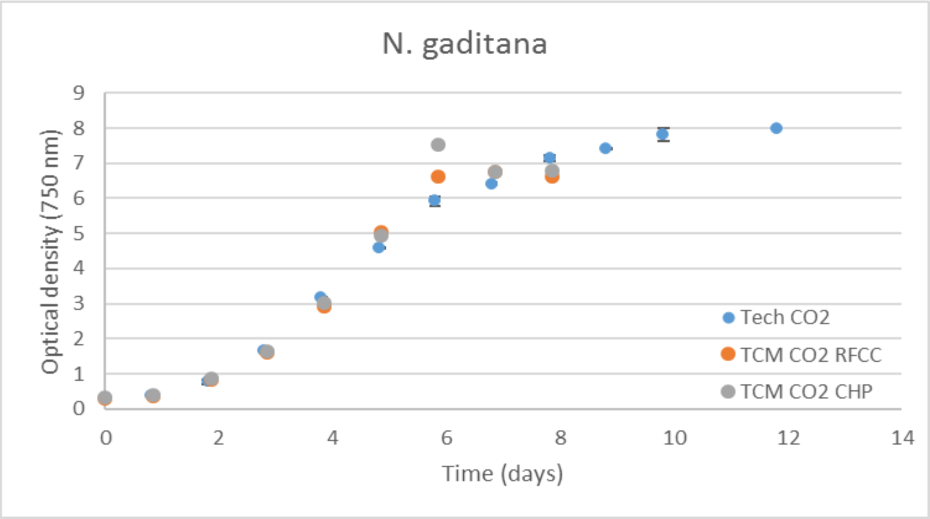
- 3 sources
  - tech $CO_2$
  - TCM $CO_2$ – RFCC
  - TCM $CO_2$ – CHP
- 3 algae
  - *Tetraselmis chuii*
  - *Nannochloropsis gaditana*
  - *Phaeodactylum tricornutum*

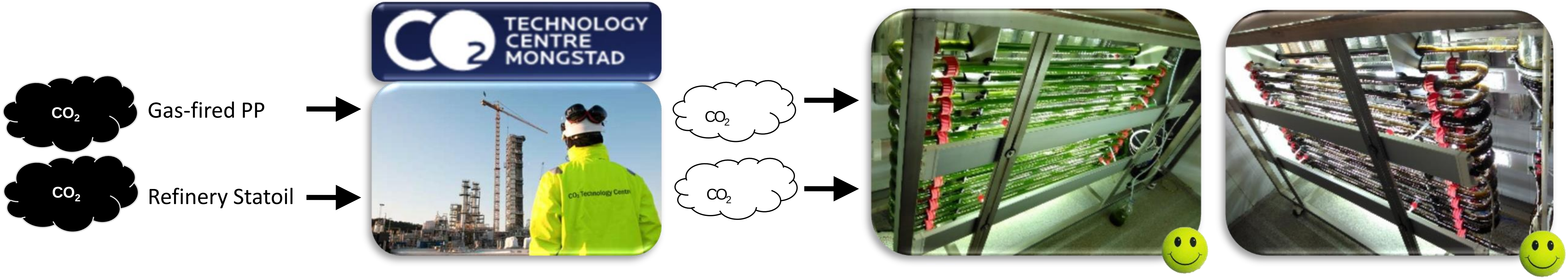


# Evaluation of different $CO_2$ sources for microalgae production

## Tested in 25L LGEM tubular PBRs:

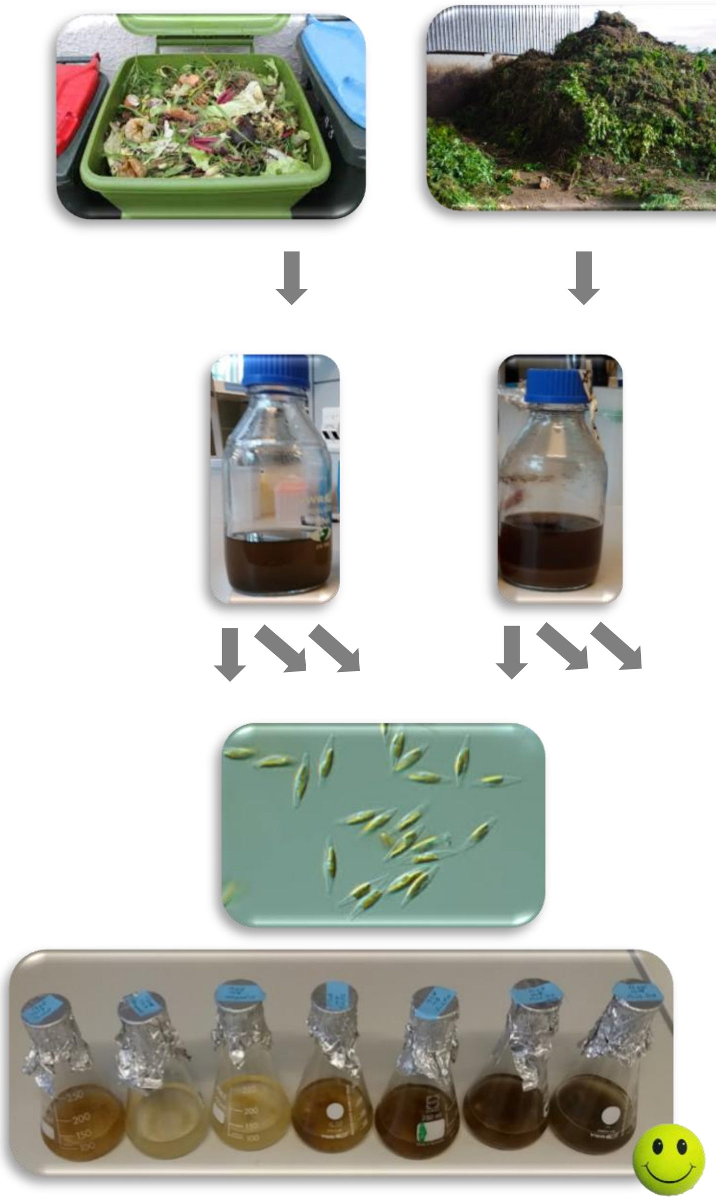
- Equal or better growth on captured $CO_2$
- Still looking into biomass quality



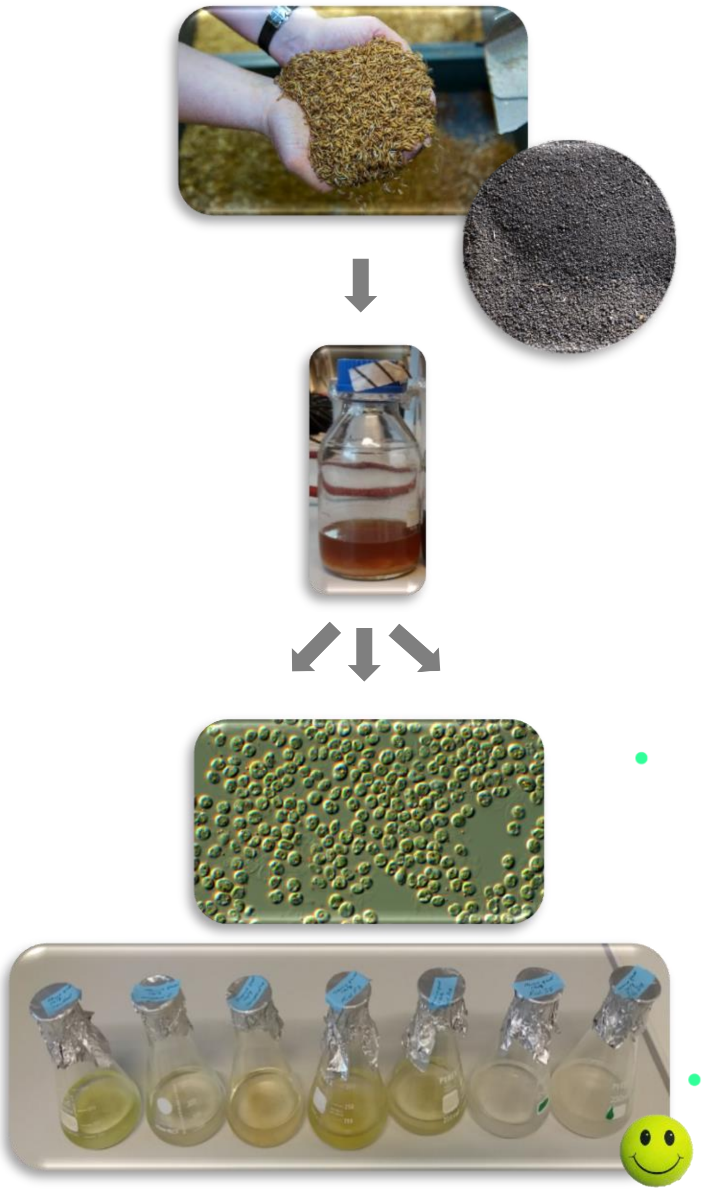



# Preliminary experiments – integration with waste streams

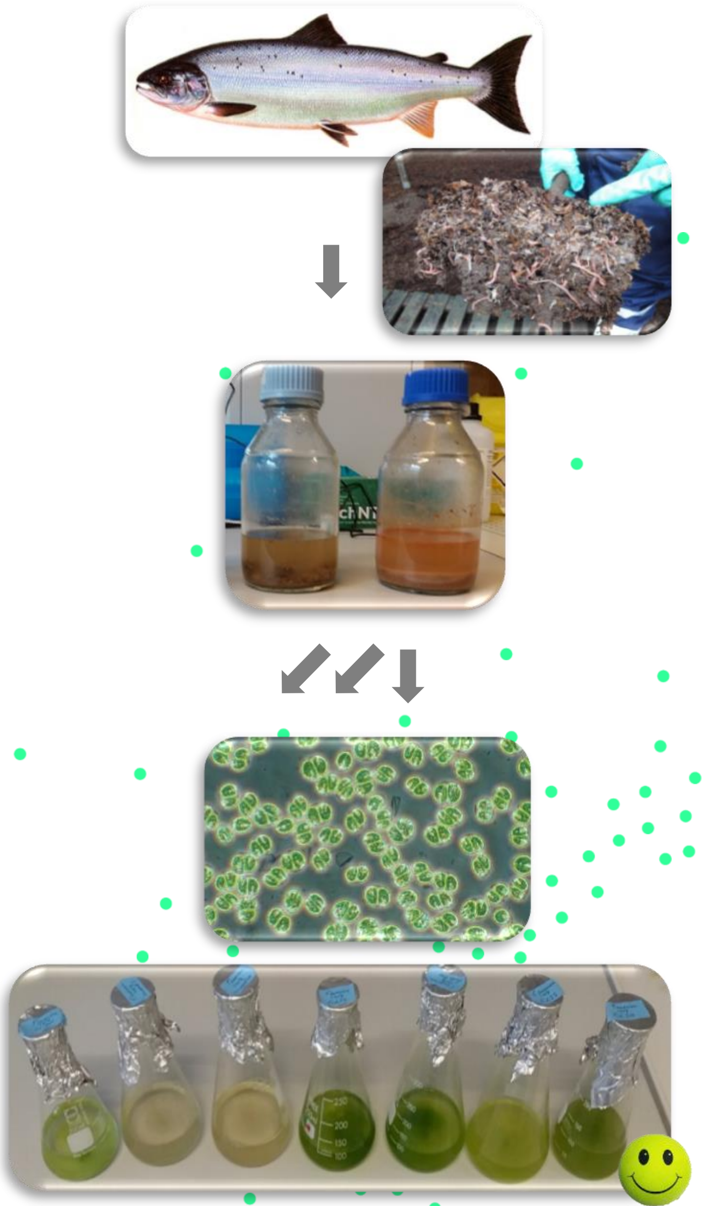
## Municipality Biodegradable Waste



## Insect manure

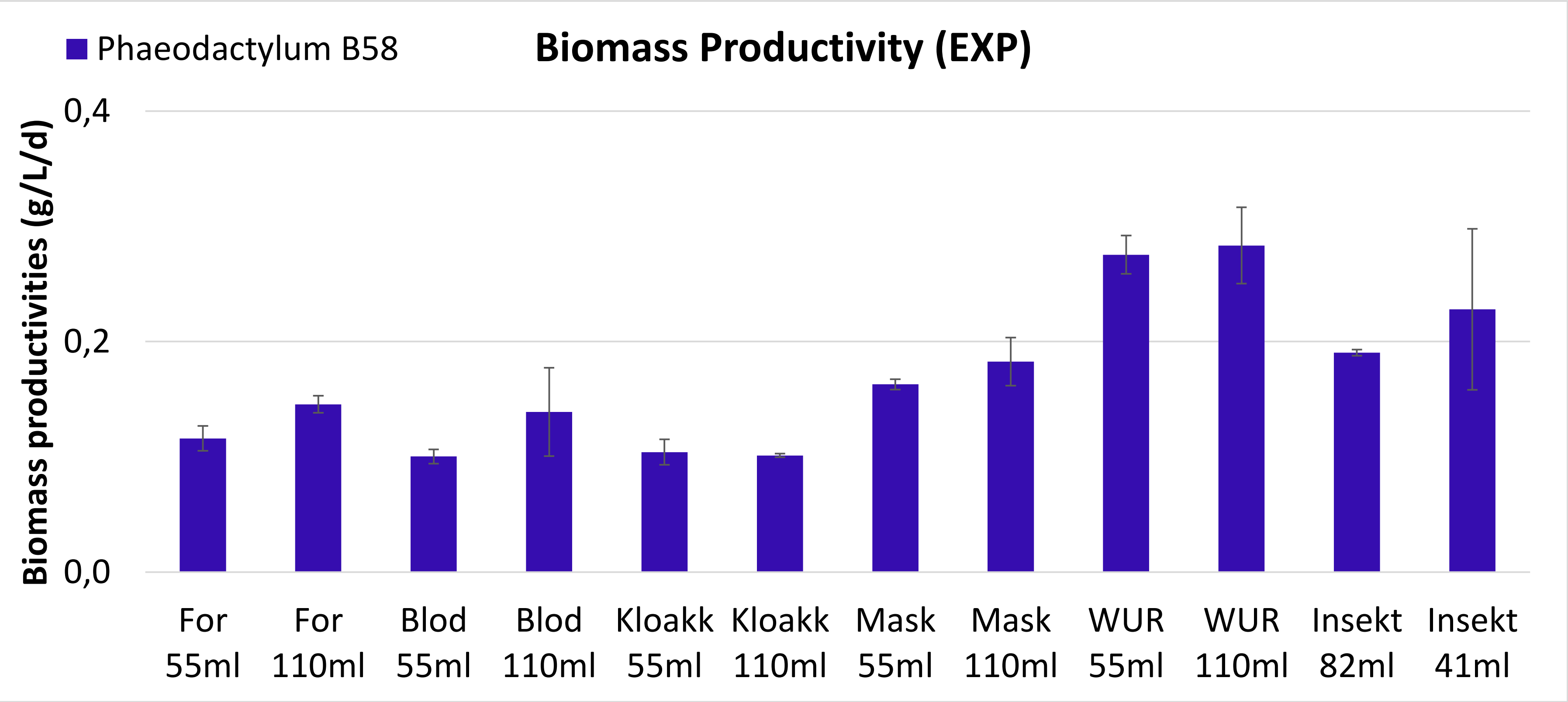


## Fish manure



# WP 1 Establish production strains and commercial cultivation media

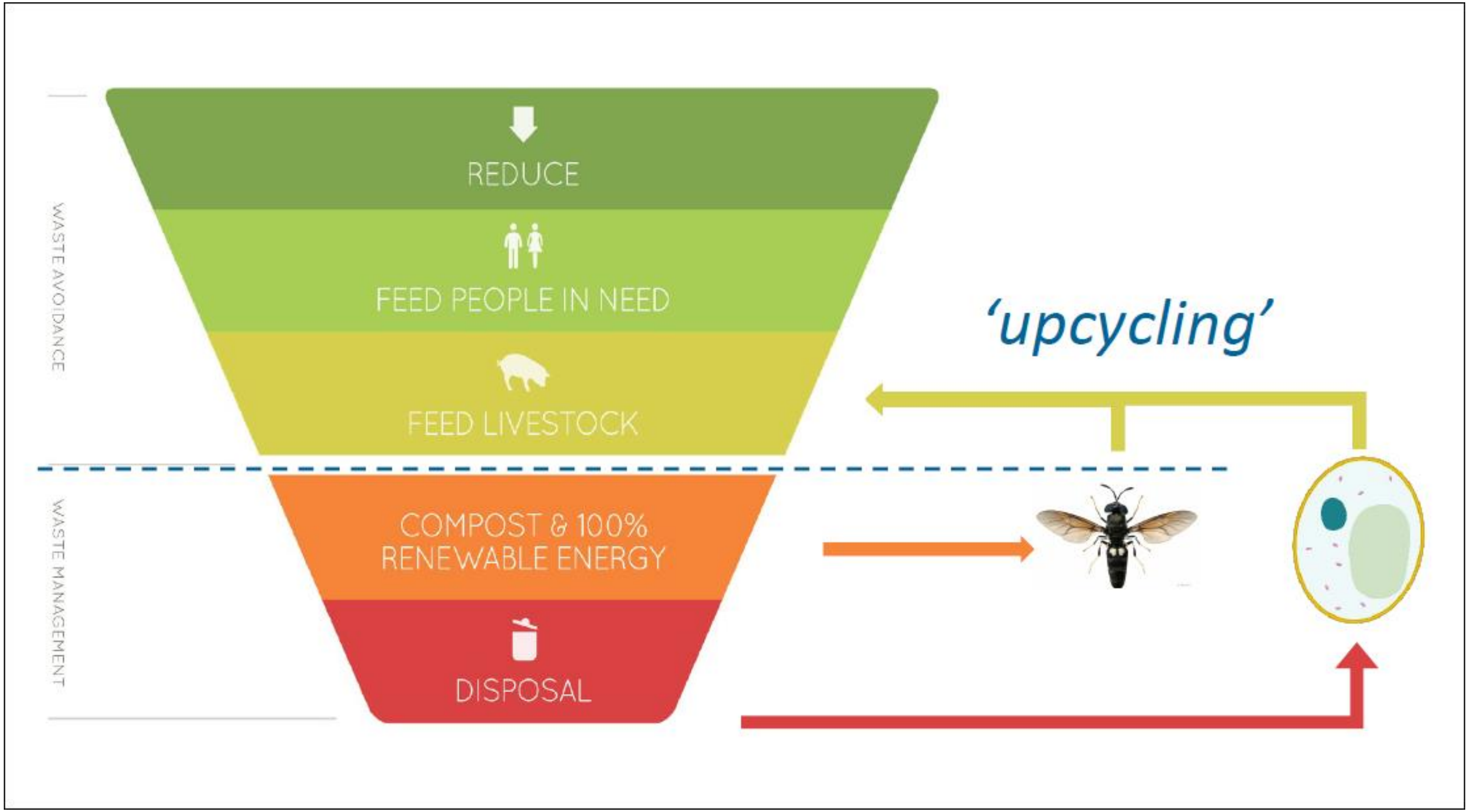
- Waste streams




Extracts of:

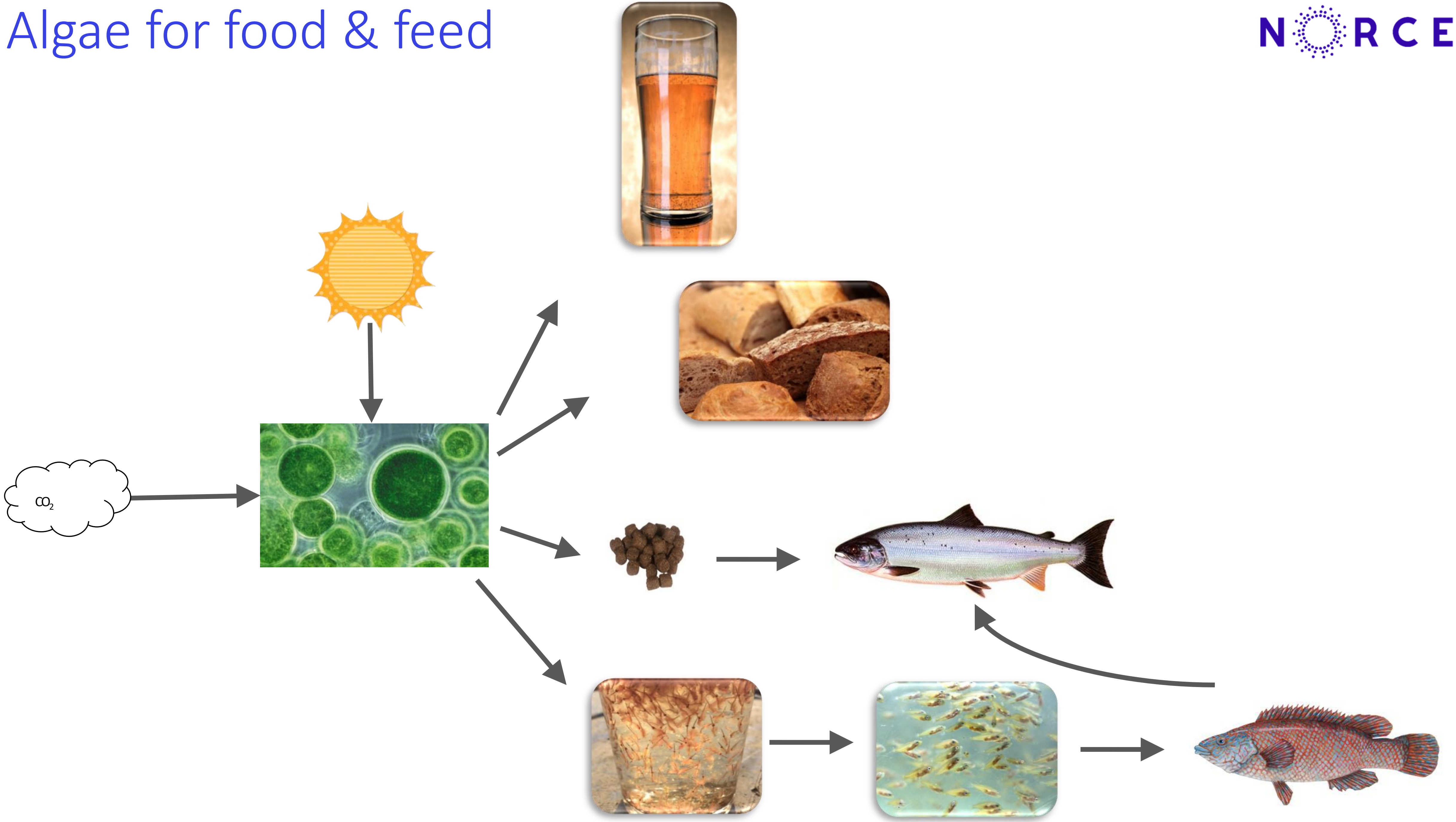
- Aquaculture waste
- Fish processing plant
- Municipal waste water
- Beer brewing waste
- WUR : standard medium
- Insect manure

# Using algae within the organic waste pyramid



# Algae for food & feed

NORCE



# Algae for plankton and fish larvae production

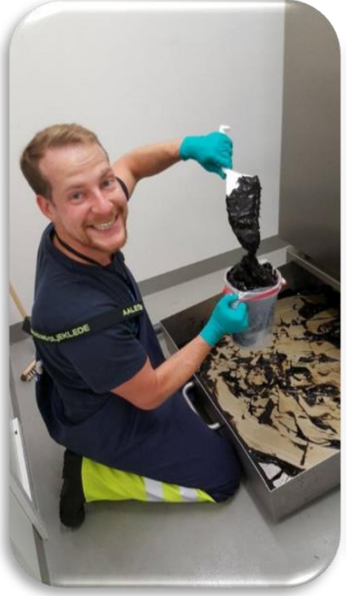
Other fish than salmon: e.g. Ballan wrasse, more difficult production process

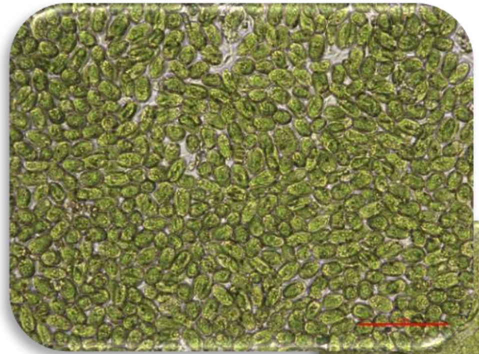
Greenwater effect

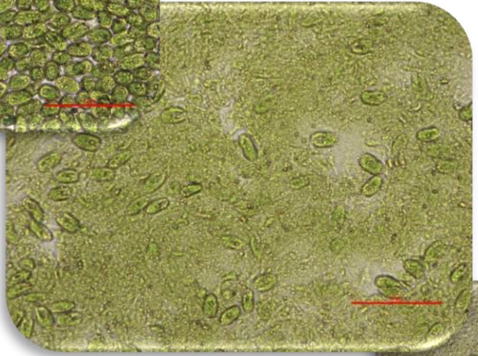
- Light filter / create shade
- Anti-bacterial agent
- In situ biological filter and produce oxygen
- Beneficial effects on health

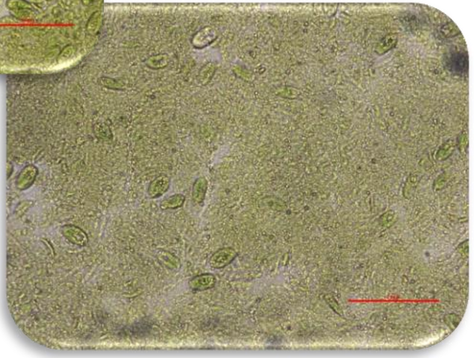
Feed / feed enrichment → direct or via copepods and rotifers

NORCE









# Thank you for your attention

Questions?

- Dorinde.kleinegris@norceresearch.no
- norceresearch.no
- @NORCEresearch