Life cycle assessment of fish feed for oil alternatives - environmental impact of microalgae, rapeseed and fish oil

Beate Zlaugotne, Jelena Pubule, Fabian A. Diaz Sanchez, Dagnija Blumberga

Biosystems Engineering 2023

European Union
European Regional Development Fund

Non-Food Organic Resources-based feeds optimised for salmon until postsmolt stage (NON-Fôr)

AIM OF PROJECT

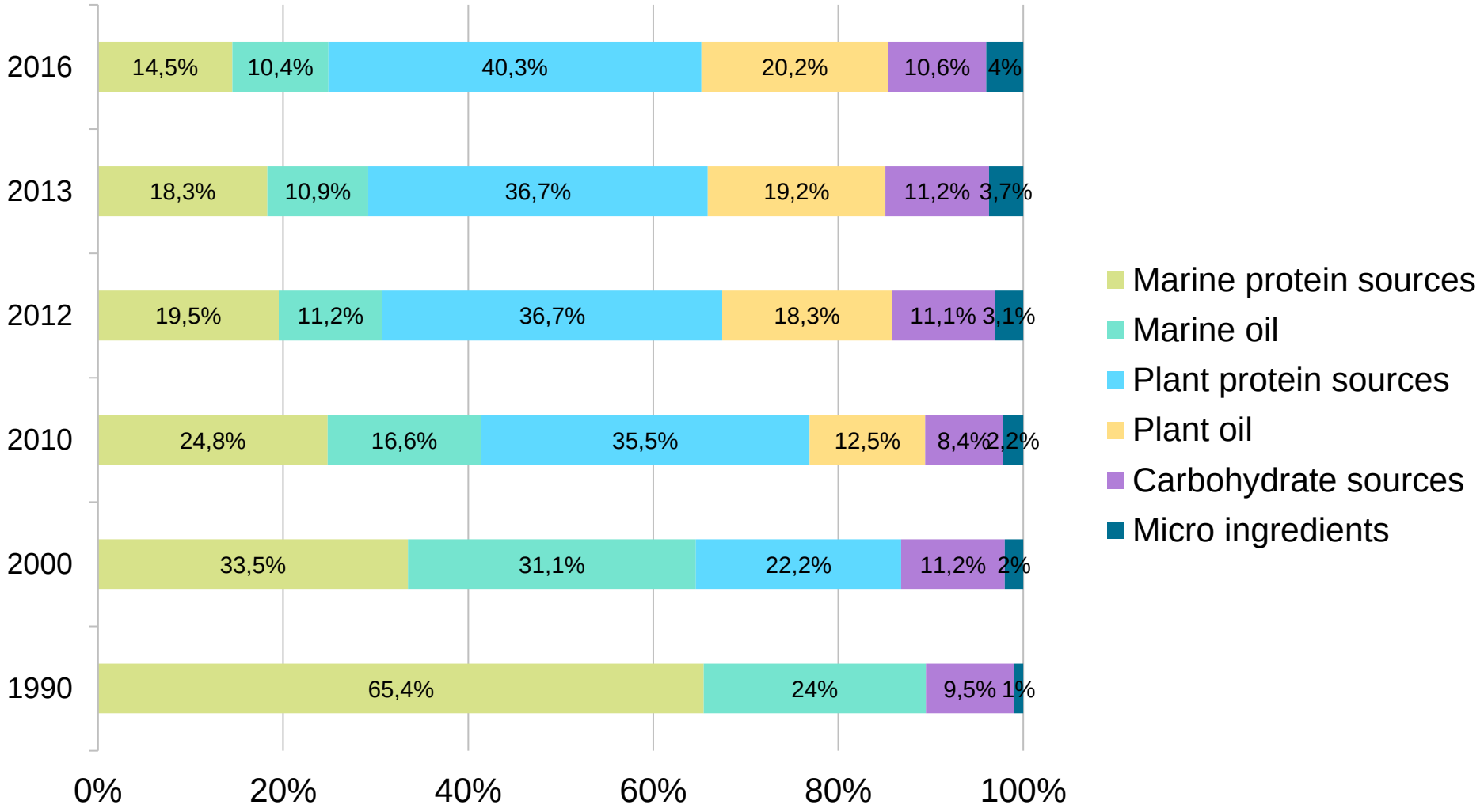
To investigate:

1. The quality of the ingredients
2. The physical quality of pellets produced by incorporating the third generation ingredients and to provide suggestions for quality improvement that can be adopted in the commercial production of these feeds
3. The potential of algae oil as replacer of fish oil at start feeding and during smoltification and the potential of insect meals as replacers of fish meal in post smolt feeds
4. The environmental impact of the new feeds

SUSTAINABILITY OF AQUACULTURE

- Over 2015-2020, total annual world **aquaculture production grew by 3,3% per year**
- Aquaculture is one of the fastest-growing food production sectors, which can provide **high-quality protein** for human consumption
- As a result, the global **demand for aquaculture products is increasing**, but its development raises concerns about the impact on the environment
- Sustainable growth of aquaculture is possible by **reducing dependence on marine resources**

COMPOSITION OF FISH FEED 1990-2016



SUSTAINABLE ALTERNATIVES

- Fish oil is traditionally used as the main lipid component in fish feed to provide the **required fatty acids**, replacing fish oil with an alternative oil is difficult due to the required fatty acids in fish feed
- The aquaculture sector **uses plant-based raw materials** to replace less sustainable raw materials in feed production
- Soybean, linseed, rapeseed, sunflower, palm and olive oils are popular **vegetable oils** which are often used in fish feed
- **Microalgae oil can replace fish oil in feed** because have a high lipid content and rich in essential fatty acids

LIFE CYCLE ASSESSMENT (LCA) STEPS

Goal and scope

- Evaluation of oil alternatives
- Functional Unit is 1 kg of oil

Life cycle inventory

- System boundaries is “cradle to gate”
- Excluded process - packaging

Life cycle impact assessment

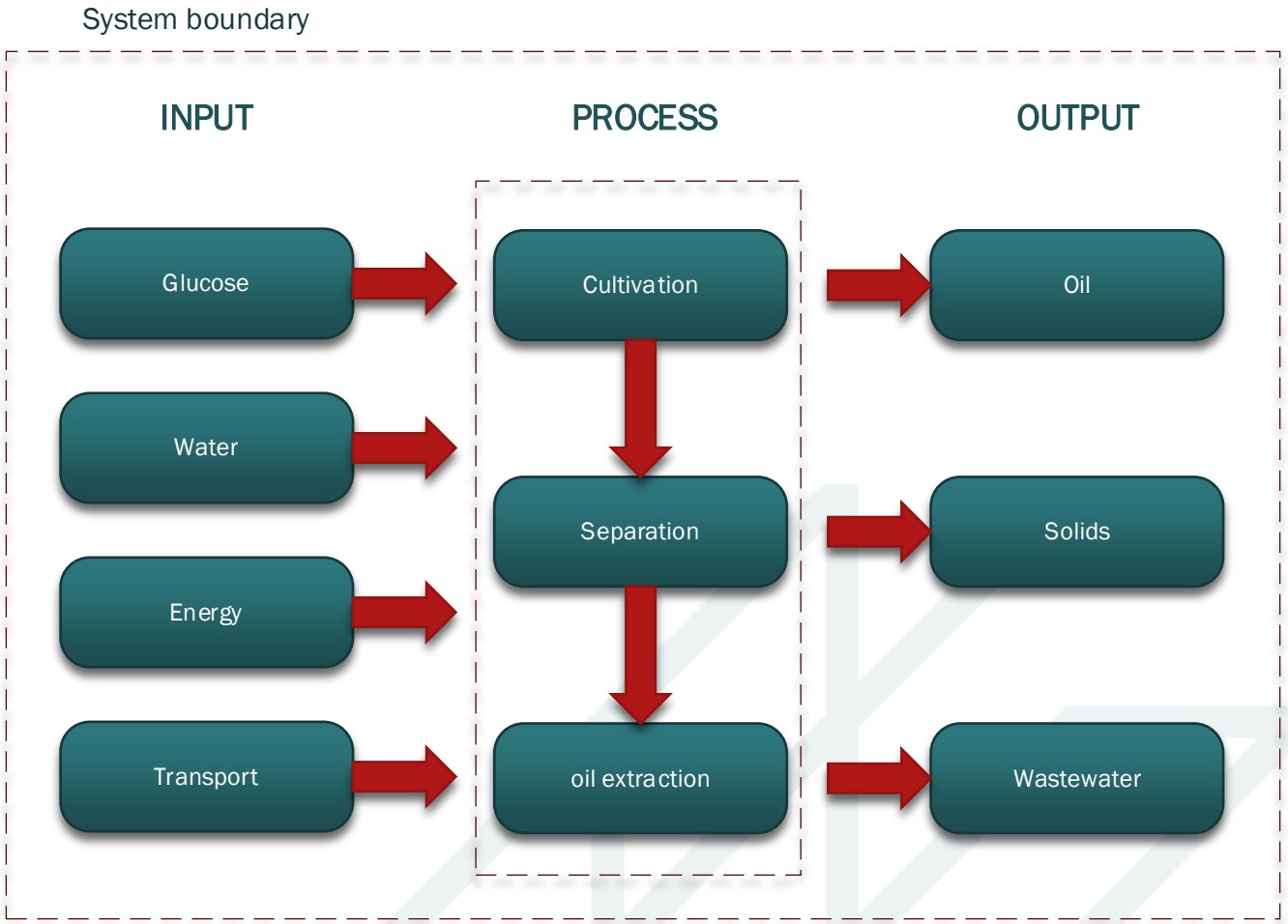
- Life cycle impact assessment is accordance with PEFCR Feed for food-producing animals
- Used method in SimaPro is Environmental Footprint (EF 3.0)

Results

- Oil assessment results for impact categories
- Sensitivity analysis assessment results for impact categories

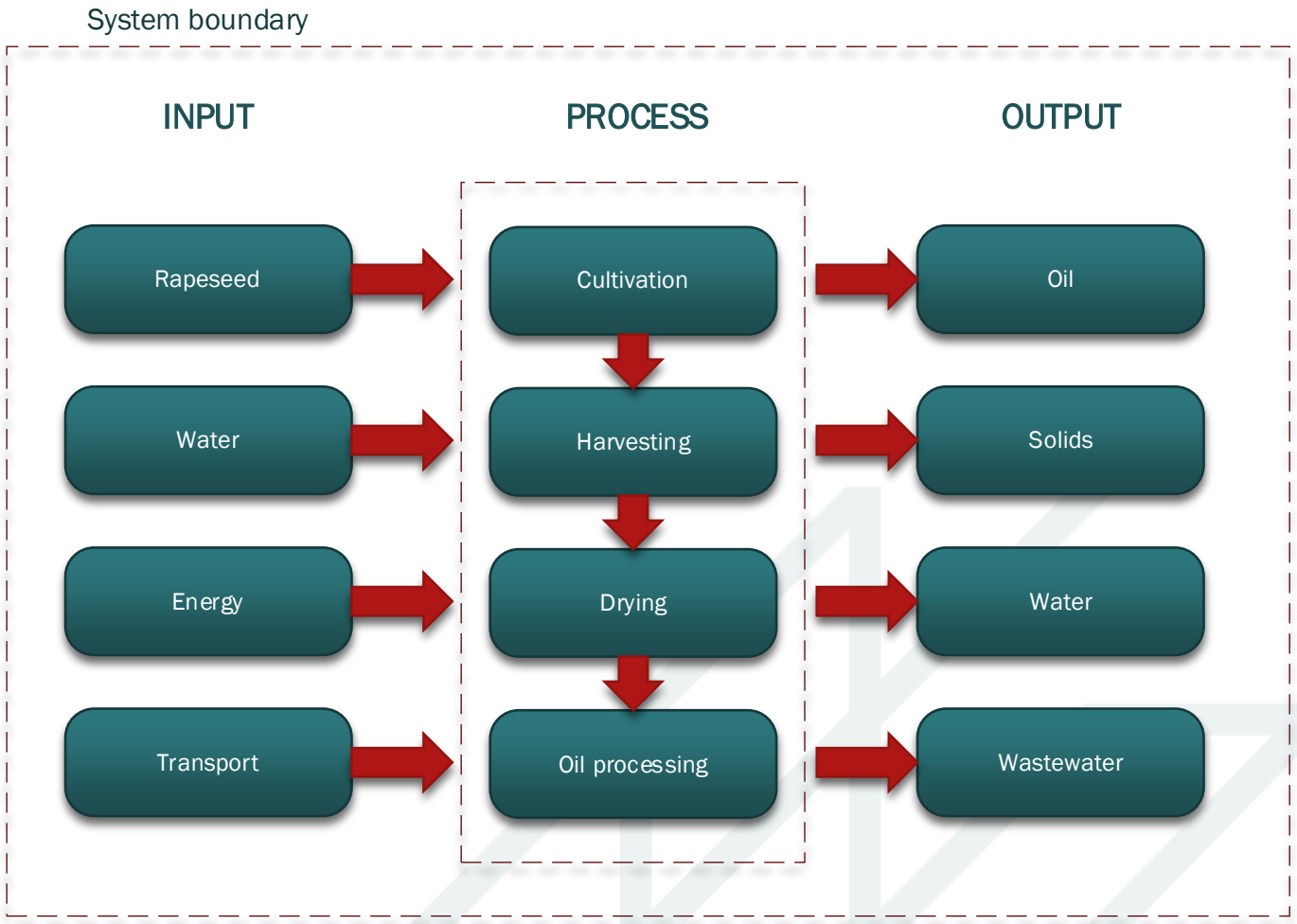
OIL ALTERNATIVE – MICROALGAE OIL

- Advantages of microalgae oil is **fast growth rate, high antioxidant** and colour content, and **availability** and also, **microalgae absorb CO_2** and removal efficiency of CO_2 is 5% to 70% and thus produce O_2 during photosynthesis
- Use of microalgae oil as lipids are **limited by high production costs**



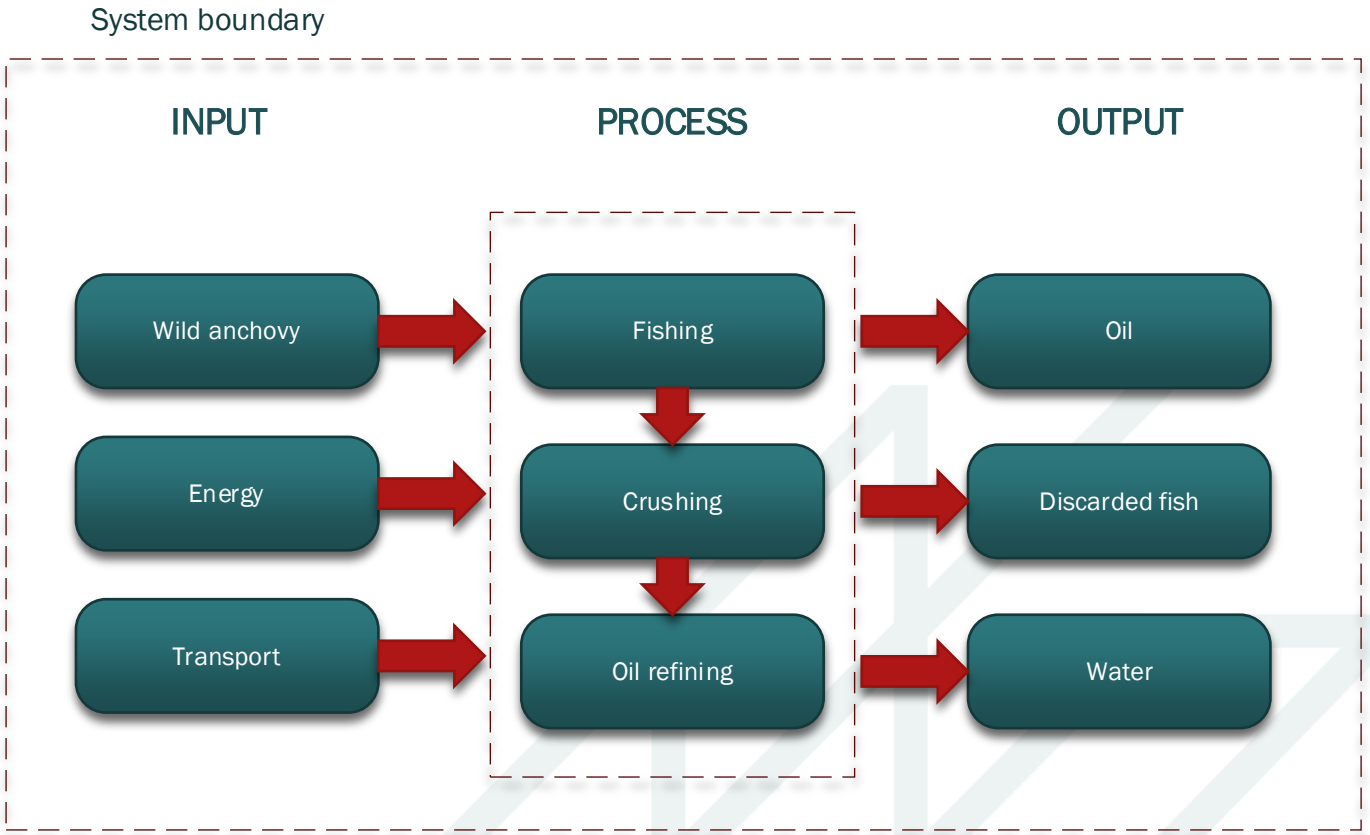
OIL ALTERNATIVE – RAPESEED OIL

- **Rapeseed oil is a suitable** lipid source for salmonids, freshwater and marine fish as it is rich in linoleic acid and oleic acid
- Replacing fish oil with vegetable oil **reduces costs**, and vegetable oils have **high availability** and **better economic value**



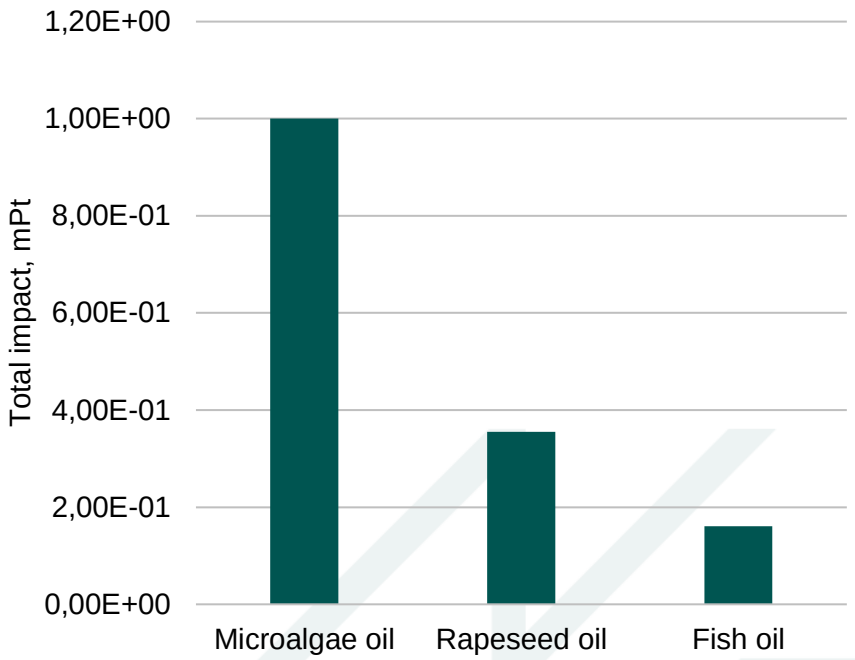
OIL ALTERNATIVE – FISH OIL

- Fish oil is obtained from pelagic fish and is used in high-energy fish feed and **12.2 kg of fish are needed to produce 1 kg of fish oil**
- Traditional aquaculture fish oil is popular and widely used, but it **impacts the environment and reduces biological diversity**



LCA IMPACT ASSESSMENT RESULTS

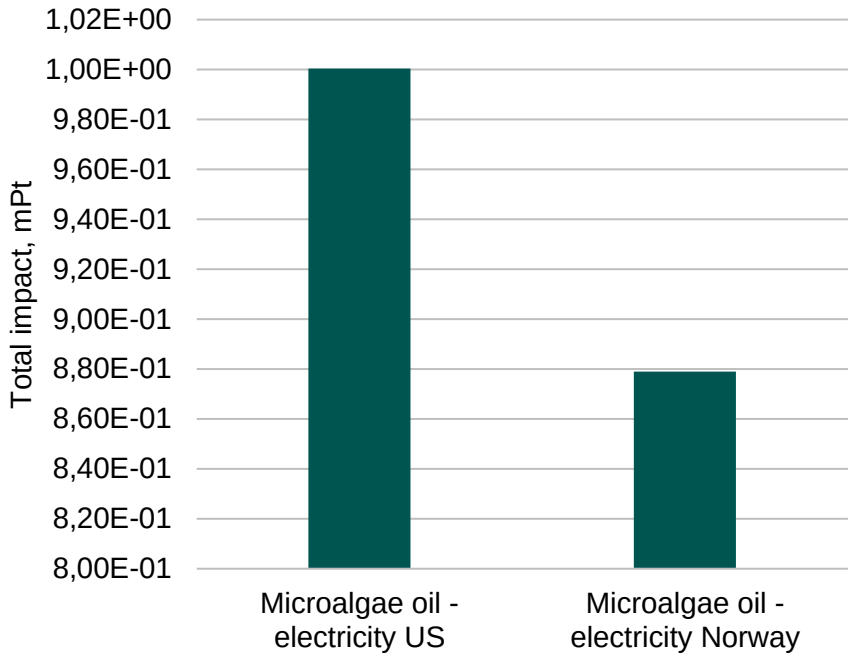
Impact category	Unit	Microalgae oil	Rapeseed oil	Fish oil
Climate change	kg $CO_{2\ eq}$	8.43E+00	1.68E+00	1.36E+00
Climate change - Biogenic	kg $CO_{2\ eq}$	3.52E-01	1.22E-03	1.14E-03
Climate change - Land use and LU change	kg $CO_{2\ eq}$	1.90E-01	2.16E-03	2.06E-03
Ozone depletion	kg CFC11 $_{eq}$	1.12E-06	1.93E-07	2.10E-07
Human toxicity, cancer	CTUh	5.56E-09	3.08E-09	8.98E-10
Human toxicity, non-cancer	CTUh	1.45E-07	1.83E-07	1.40E-08
Particulate matter	disease inc.	4.42E-07	2.91E-07	1.45E-07
Ionising radiation	kBq U^{235} $_{eq}$	1.23E+00	9.52E-02	6.27E-02
Photochemical ozone formation	kg NMVOC $_{eq}$	2.37E-02	6.67E-03	1.19E-02
Acidification	mol $H+$ $_{eq}$	5.16E-02	4.28E-02	1.75E-02
Eutrophication, terrestrial	mol N $_{eq}$	1.54E-01	1.84E-01	4.45E-02
Eutrophication, freshwater	kg P $_{eq}$	3.34E-03	5.11E-04	1.62E-04
Eutrophication, marine	kg N $_{eq}$	1.75E-02	4.07E-02	4.16E-03
Ecotoxicity, freshwater	CTUe	2.19E+02	5.50E+01	1.46E+01
Land use	Pt	4.71E+02	1.87E+02	4.05E+00
Water use	m^3 depriv.	1.07E+01	1.22E+00	6.21E-01
Resource use, minerals and metals	kg Sb $_{eq}$	9.35E-05	1.29E-05	1.03E-05
Resource use, fossils	MJ	1.12E+02	1.28E+01	1.93E+01



Pt is the unit of the eco-indicator, and 1 Pt is representative of one thousand of the annual environmental load of an average European citizen

LCA SENSITIVITY ANALYSIS

- Sensitivity analysis was for Microalga oil alternatives – in one case, for production, it was used **electricity in the US** and in another case was used **electricity in Norway**
- If production takes place in **Norway, the impact of the electricity used has less impact** on the environment than if production takes place in the US using US electricity



Pt is the unit of the eco-indicator, and 1 Pt is representative of one thousand of the annual environmental load of an average European citizen

CONCLUSION

- Results from LCA shows that the **largest impact is from microalgae oil**, than rapeseed oil and folowed by fish oil
- The largest impact of **microalgae oil alternative is from glucoses and electricity consumption**, impact can be reduced by using a greener electricity mix and more sustainable glucoses
- For **rapeseed oil alternative largest impact is from rapeseed**, and it is because of intensive or extensive cultivation processes and to reduce the impact it is better to choose organically grown rapeseed
- For **fish oil largest impact is from using fresh landed anchovy** and to make a less impact it is possible to use more fish residues as main input for fish oil production
- The results show an **overall picture** of the impact of oil alternatives used in fish feed production

CONCLUSION

- In the literature on the studies carried out comparing fish oil with algae oil, the result is that **algae oil has a less impact on the environment**
- The difference in the results is because the literature used a **different method for the impact on the environment measuring** and also **the functional unit** was the amount of EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid)
- The study can be **further developed by comparing fish feeds** where there are changes in the ratio of ingredients
- The obtained results show the impact of oils alternatives on the environment, but the **quality of the feed is important** in the production of fish feed, both in terms of **physical properties and composition**
- These **characteristics also affect the growth of the fish** and how valuable the fish is in the human diet

This work was supported within the framework of the European Regional Development Fund project No. 1.1.1.5/17/I/002 “Integrated national level measures for strengthening interest representations for research and development of Latvia as part of European Research Area” by funding project No. 23-11.17e/21/165 “Non-Food Organic Resources based feeds optimised for salmon until post-smolt stages”(NON-For).

European Union
European Regional Development Fund

Institute of Energy Systems and Environment

RTU IESE

Prof., Dr.sc.ing. Jelena Pubule
jelena.pubule@rtu.lv