Life Cycle Assessment of RAS fish farm in Sweden

AG2800 Life Cycle Assessment

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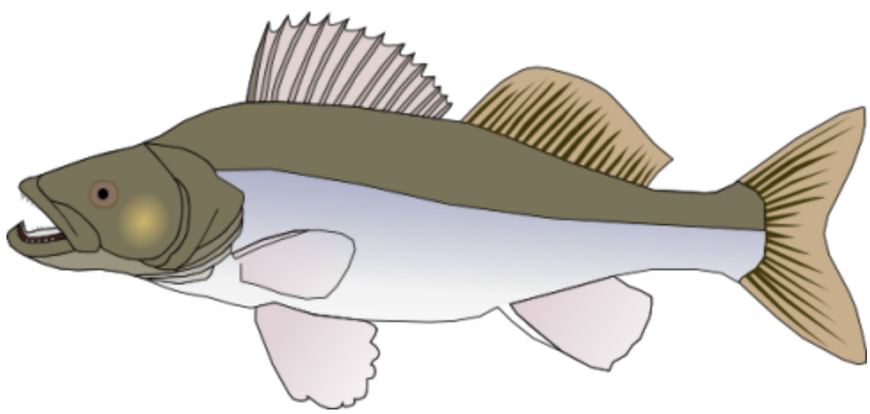

Abstract

The high consumption of food today and future needs means many challenges. Marine and freshwater ecosystems are under heavy human pressure due to overfishing and emissions. Declining catches is a prof telling that something needs to be changed.

One possible way is to develop Recirculating Aquaculture System (RAS) further. These land based fish production sites have the advantage of reducing the use of water and wastewater emissions. The plants will also reduce the distance between production site and market, meaning less transports. The RAS plants are undergoing steady development and acts as one potential solution for securing future demand of fish supply.

This paper analyses the RAS located at Ljusterö in the Swedish archipelago, where Pike Perch is cultivated. An LCA where performed in order to identify hotspots for improvements on the Ljusterö RAS. The selected functional unit was one kilo of edible fish fillet and the LCA was performed in SimaPro using its databases.

The biggest drivers for environmental impacts where identified to be the fish feed and electricity. To solve these issues, flows need to be further optimized and the waste minimized or utilized in the best possible way. The recommendations are to change the feed and optimize the electricity system on the plant.

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1. Introduction

Today our food consumption faces many challenges. The ecosystems of fishes are over fished and even thou this is a fact the exploitation continues. The result is stagnating or for most fish ecosystems; declining catches (Jackson *et al.*, 2001). One way to overcome this dilemma is to construct land based fish production sites. One technical innovation for land based fish production is the Recirculating Aquatic System (RAS) plant. The RAS does not only have the advantage of reducing the use of water, wastewater emissions but it will also reduce the distance between production site and market. The potentials RAS have are extent and it is one potential solution for securing a future demand of protein. The plant's environment is closely controlled with high biosecurity (Queensland Government, 2014). The principle of the studied RAS is shown in figure 1.

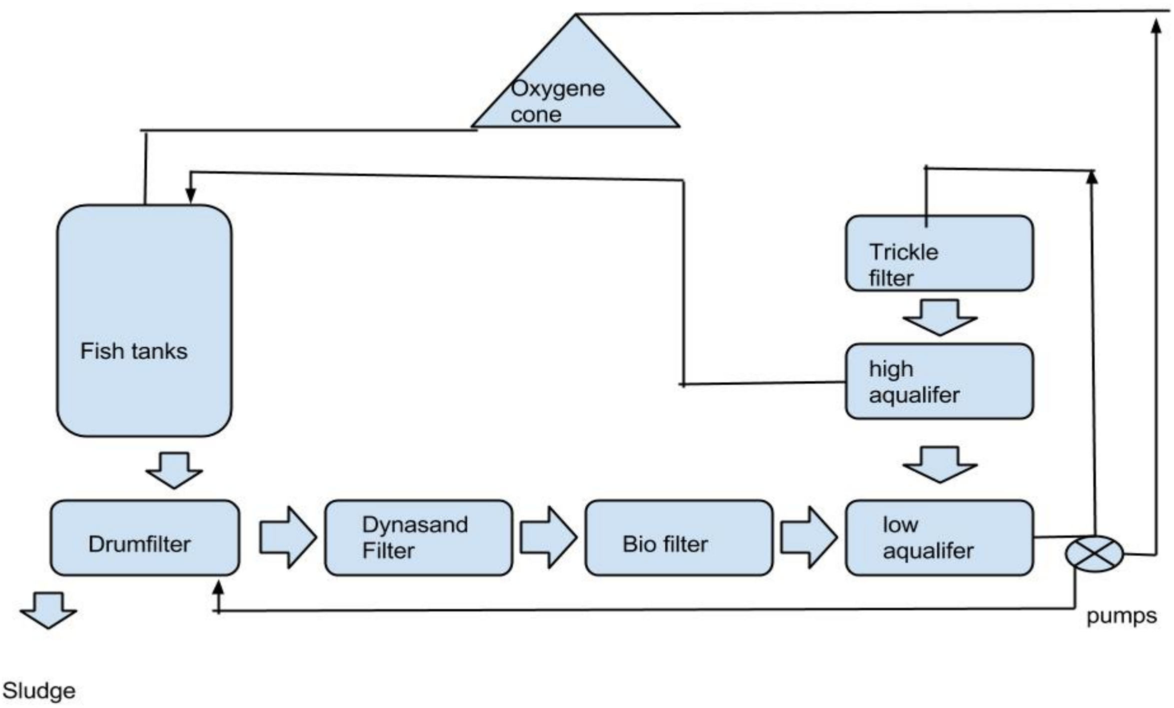

Figure 1. *Simplified flow chart over the RAS-technology*

To understand the impacts caused by an RAS an LCA study is carried out on a RAS plant located at Ljusterö, in the Stockholm archipelago. The Ljusterö plant is a pilot project with a yearly production of around 3-5 tonnes of Pike Perch for food. The plant has the ambition to expand and in the future produce fish on a larger scale (Svenskt Vattenbruk, 2014).

The aim of this LCA study is to identify potential hotspots for improvements. This is achieved by identifying the parts that contributes the most to the environmental impacts. Further, it would then be possible to identify where improvements can be made in the products life cycle. The authors have in collaboration with the department of Industrial Ecology at KTH developed the goal and scope for the LCA. According to Baumann and Tillman (2004) questions concerning the possible environmental impact caused by a product implies an accounting LCA. Initially a stand-alone analyse will be performed that can, if developed further, be expanded to a comparative analyse. Further, the conducted LCA will be an attributional type which means that the data used is average. For the LCA modelling the program SimaPro is going to be used.

The system has 6 fish tanks where five of those house Pike Perch fishes. In the real situation the remaining tank contains Perch, though in this LCA it is assumed that all six tanks house Pike Perch. The water is recalculated by two pumps and is kept at a temperature around 22° Celsius. Due to the Swedish climate the Ljusterö RAS is located indoors.

1.1. Goal of the study

The research question is to identify hotspot for improvements on the Ljusterö RAS.

1.2. Functional unit

The Ljusterö RAS produces Pike Perch for human consumption. About 40 % of the produced fish can be sold as fillet (Öberg, 2014). The functional unit is one (1) kg of edible Pike Perch fillet. The LCA model used is going to account for the whole lifespan of the RAS fish farm, which was estimate to be 50 years. This means some equipment with lower life span will be replaced.

1.3. System boundaries

The process system boundary was chosen to make a cradle-to-gate LCA, shown in figure 2. This decision was made because the research question is to find the impact hotspots for this particular fish farm.

The main part of the RAS is cultivation, meaning the tanks and water system where the fish is feed up. For the cultivation there are three main things needed. These are the feed, the Pike Perch spawn and the RAS equipment. The equipment will be explained further on in the report. The Pike Perch spawn is collected from the wild and bought in to the fish farm once per year. Since the cultivated fish are carnivore the feed needs to contain animal protein, in this feed in form of fishmeal. The feed is bought ready-made for cage fish farms. Both slaughter and filleting is supposed to be done by hand on sight, meaning that no transportation is needed.

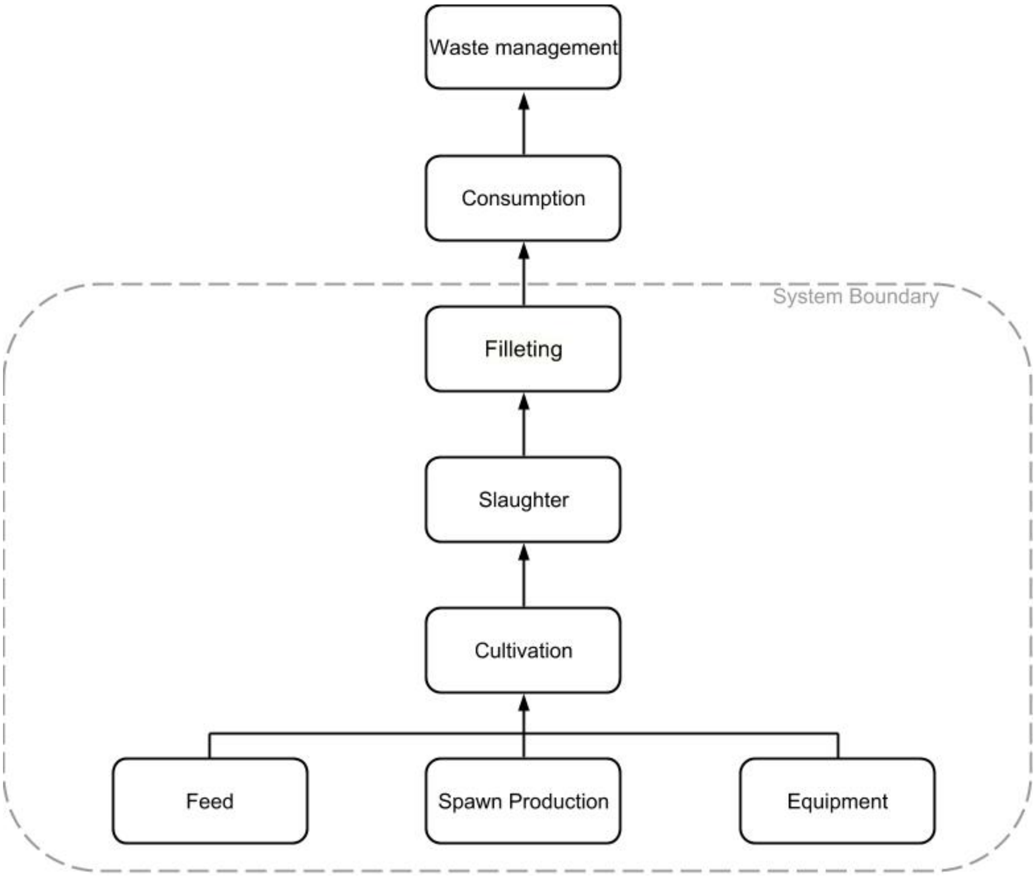

Figure 2. *Simplified flow chart over the processes and system boundary*

Time boundaries

The time boundaries are based on data from past assessment. The data derives from when the materials where taken into use. The data used in SimaPro are updated and actual. The data does not include long-term emissions and the long-term impacts follow midterm emissions according to the normalisation model ReCiPe.

Geographical boundaries

The fish farm itself is located in the Stockholm archipelago and the electricity for the fish farm is calculated according to the average Swedish mix. Concerning material extraction and production this will take place all over the globe and therefore the boundaries are not set only to the Stockholm archipelago.

Allocation procedure

Our allocation problem is categorised as multiple output, and is between the fish fillet and the fish waste that goes to biogas. We are going to calculate it by the physical relationship of weight percentage between the fish fillet and waste. The produced biogas are going to be calculated as avoided burden.

1.4. Limitations and Assumptions

To make this LCA possible several assumptions and limitations had to be made. Firstly that only pike perch is going to be produced in all six fish tanks and that slaughter and filleting is made on sight which means no transportation is needed. The fish waste that is produced in the filleting stage, 60 % of the weight of the whole fish, is assumed to be used for biogas. The sludge produced by the water treatment is composted for use as a fertiliser, though no avoided burden is going to be calculated for the compost due to uncertainties in what is being substituted. Also it is assumed that no water will evaporate, though this is the case in reality.

For the equipment only the main components is going to be included except for the data for the two pumps and the heat pump which will be taken from SimaPro databases. The equipment for filleting and slaughter is excluded. The End of Life and the manufacturing of the equipment are going to be excluded due to the low impact of the equipment itself.

1.5. Impact categories and impact assessment methods

For the SimaPro analysis the ReCiPe (H) Midpoint method was used. A midpoint methodology is looking at the impact at an earlier stage than an end-point methodology does which also means they are more precise. ReCiPe has eighteen different mid-point indicators (ReCiPe, 2008);

- Climate change
- Ozone depletion
- Human toxicity
- Photochemical oxidant formation
- Particulate matter formation
- Ionizing radiation
- Terrestrial acidification
- Freshwater eutrophication
- Marine eutrophication
- Terrestrial ecotoxicity
- Freshwater ecotoxicity
- Marine ecotoxicity
- Agricultural land occupation
- Urban land occupation
- Natural land transformation
- Water depletion
- Metal depletion
- Fossil depletion

1.6. Normalization and weighting

For this study a normalisation based on ReCiPe midpoint (H) Europe was performed, which compares the impact indicator with the average impact of an European citizen. Weighting is going to be excluded because the outcome highly depends on subjective opinions.

2. Inventory analysis

In the inventory analysis phase of the LCA the processes involved are going to be identified, a detailed flow chart is going to be drawn and data is going to be collected. In this phase the SimaPro model was created.

2.1. Process flow chart

Figure 3 illustrates the flows in more detail. The figure describes the system boundaries with the foreground system, which contains the processes that can be controlled by the decisions made in the study. The other processes, the background system, are included in the study due to its connection and dependence on the decisions made in the foreground system.

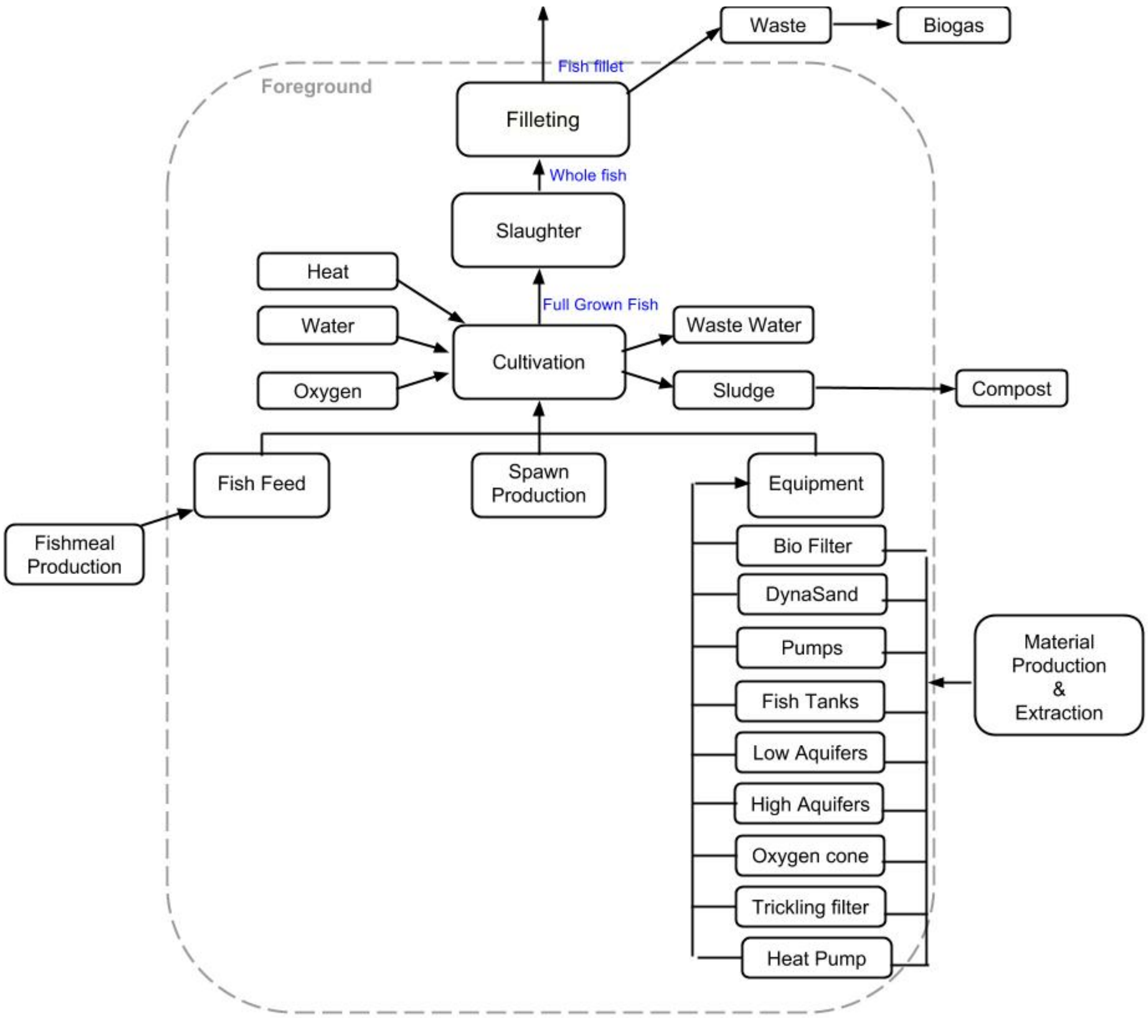

Figure 3. *Detailed process flow chart*

Most of the equipment have the function to clean the water but in order to run the RAS successfully all parts are needed. In figure 3 the input and output flows in the cultivation stage are also added. The inputs derive from heat, water and oxygen and the outputs are wastewater and sludge, where the sludge is used as compost. Another output is the waste produced in the filleting stage. This waste, mainly fish guts, is used for biogas production.

2.2. Data

The specific equipment data used at the Ljusterö fish farm was given by Ola Öberg (2014) and can be found in appendix I. The raw data was recalculated to be consistent with the functional unit.

Equipment

Concerning the equipment the weight of each of the foremost used materials was calculated, shown in table 1. The data for the two pumps and the heat pump was taken directly from SimaPro databases to approximate the real equipment at the Ljusterö Fish farm. For the background processes which is material extraction and production, data from the SimaPro databases was used.

Equipment	Material	Amount
Fish tank	Fibre glass	3200 kg
Oxygen cone	Stainless steel	442.4 kg
High Aquifers	Same as fish tank	
Low Aquifers	Swivel block lined with fibre glass reinforced PVC	3923.5 kg clay 53.2 kg PVC
Bio-filter	Same as low aquifers	
DynaSand filter	Stainless steel	1838 kg
	Sand	2340 kg
Trickling filter	Fibre glass	3200 kg
	Stainless steel	500 kg

Table 1. *Material data for equipment*

The only equipment that needs to be replaced during the life of the farm is the pumps and heat pump. The two pumps have a lifespan of 15 years each, meaning we are going to need 6.67 pumps in total during the 50 years. The heat pump lasts for 20 years, meaning the farm will need 2.5 during the 50 years.

Inputs and Outputs

The inputs to the production are related to the cultivation step, see figure 2, and the data can be seen in table 2. As explained in the unit column all data is calculated per whole fish, and not fillet, this is done because the production of the whole fish is going to cause an impact. The Ljusterö RAS is at the moment producing 20 kg of whole fish a day.

Input	Unit	Amount
Electricity	kWh/kg whole fish	16.67

Water	kg /kg whole fish	0.43
Fish feed	kg/ kg whole fish	3.43
Spawn	g/kg whole fish	3.29
Oxygen	kg/ kg whole fish	0.58

Table 2. *Data inputs to the fish farm*

The fish feed data was taken from the databases in SimaPro, but the only fish feed found was for trout. It comes from a consequential LCA located in Denmark and the fish oil in the feed has been substituted with rapeseed oil. The electricity and water used was also taken from the databases, and as mentioned before the electricity is the Swedish average mix.

The outputs of the Ljusterö RAS derive from the both cultivation and filleting. The output data is calculated per whole fish and can be seen in table 3.

Output	**Unit**	**Amount**
Waste water	kg/kg whole fish	0.43
Sludge	kg/kg whole fish	0.69
Fish waste	kg/kg whole fish	0.6

Table 3. *Data outputs from the fish farm*

2.3. Modelling in SimaPro

The model in SimaPro is going to be for one kg of fish fillet, which means that the cultivation step has to produce 2.5 kg of whole fish since 40 % of the fish is fillet (Öberg, 2014). Furthermore 1.5 kg of fish waste is generated in the process. In order to get correct calculations for the equipment, it needs to be expressed in the unit of kg fish. It is calculated by a conversion factor that summarised how much fish that would be produced during 50 years in the case of a daily fish production of 20 kg whole fish. Equation 1 shows how the conversion factor was calculated:

$$\frac{1\ equipment}{20\frac{kg}{day}\cdot 365\frac{days}{year}\cdot 50\ years} = \frac{1}{365\ 000}\ equipment\ /\ kg\ whole\ fish$$

Equation1. *Calculation of the conversion factor*

In figure 4 the whole SimaPro model is shown. The model is shown with a cut-off at 13% and characterized results for human toxicity.

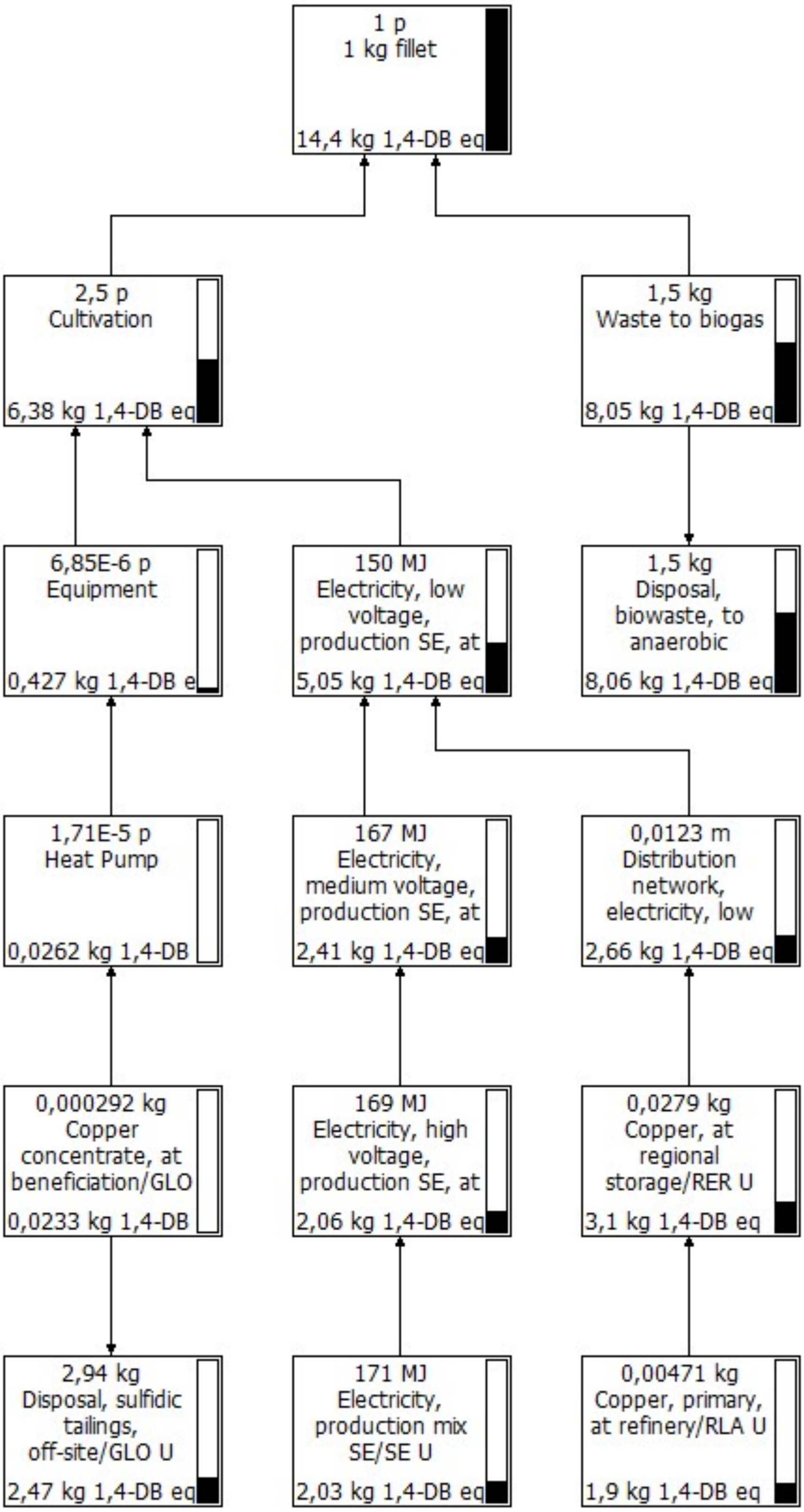

Figure 4. *Model in SimaPro of characterized results of human toxicity with cut-off at 13%*

3. Life cycle interpretations

In order to assess the impact from the fish fillet the results from the LCA are interpreted into environmentally relevant information. This is done through classification and characterisation method that translates the environmental load into impacts (Braumann and Tillman, 2004). Normalized values shows on the impact range compared to Europe's average citizen impacts.

3.1. Results

For the total result presentation ReCiPe midpoint is used and shows results per functional unit or for kg fish. It can be seen that the cultivation process is the part contributing highest in most of the impact categories, see figure 5. This characterizing bar graph shows on the relative impact of one kilo of fish fillet.

When analysing the graphs one can see that the biogas process, green areas, have a large impact when it comes to terrestrial eco toxicity and human toxicity. For these two categories the contribution from biogas production is significant. The most reasonable answer for why the biogas process scores such high in these categories and not in the others are probably due to the occurrence of anaerobic digestion. When looking at the results in more detail it was found out that the substance influencing the most in the biogas process where phosphorous. For all of the other impact categories the cultivation process scores higher on relative impacts.

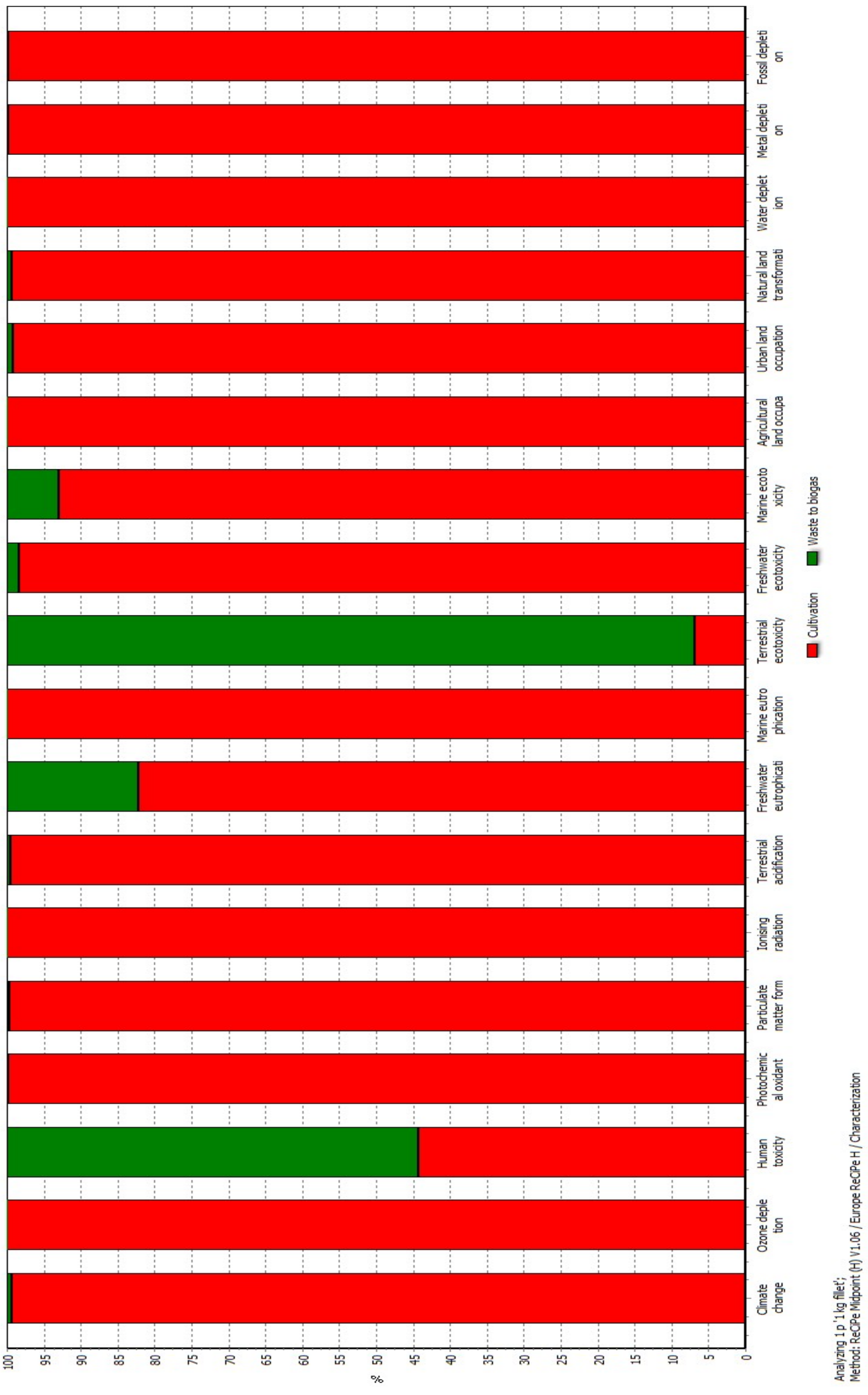

***Figure 5**. Characterised results per 1kg fish fillet for whole process*

In figure 6 the normalized results are presented. In this graph the impacts relative to the emissions in Europe are presented. The result shows that human toxicity and terrestrial eco toxicity are the biggest normalized impacts. According to this comparative method land occupation and water depletion have low impact contributions.

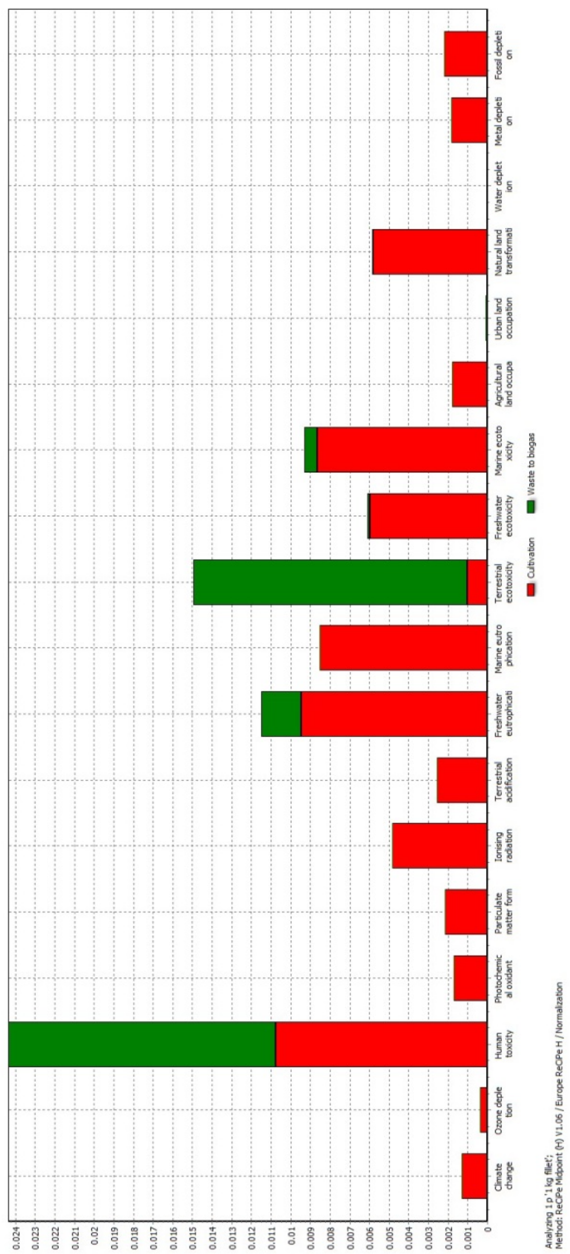

Figure 6. *Normalized result for whole process*

Figure 7 illustrates the wide range of impacts per functional unit for each separate process within the cultivation. For a complete table of values per kg fish, see Appendix II.

The fish feed, represented by the red bars, has its largest contribution and impacts within fossil fuels and climate change. The high impacts within these categories can be related to high emissions from diesel and oil extraction and combustion. The diesel use in fish feed production is the main driving force for the emissions. 3.68kg crude oil is used for producing 1kg of fish fillet. Further, the diesel and oil for heating is a contributing factor to human toxicity while photochemical oxidants and particulates are another effect of diesel use. The terrestrial acidification is connected to SOx emissions from diesel and rapeseed production. The marine eutrophication is a burden of rapeseed and wheat. Finally, agricultural land occupation is an effect of rapeseed and wheat agriculture.

The pink bars correspond to the impact of the electricity. The electricity is dominating for human toxicity, ionising radiation, freshwater eutrophication, terrestrial eco toxicity, marine eco toxicity, land occupation and transformation, water depletion and metal depletion. The reason why it has such an impact within the area human toxicity is due to use of manganese. The manganese potential impact comes from copper usage and nuclear power generation. The ionising radiation is a result of the nuclear materials. Freshwater eutrophication is caused by sulfidic tailings in copper production. The terrestrial eco toxicity is an effect of the disposal of wooden ash. The copper extraction, sulfidic tailings and nuclear reactions all contributes to the impacts on marine eco toxicity. Land occupation is caused from infrastructure of power plants and grid infrastructure. Water use at nuclear power plant contributes to water depletion and metal depletion is represented by copper use.

The equipment, represented by the yellow bars, has low impact within all categories. The blue bars describe the wastewater treatment where the largest impacts are caused by phosphates resulting in eutrophication.

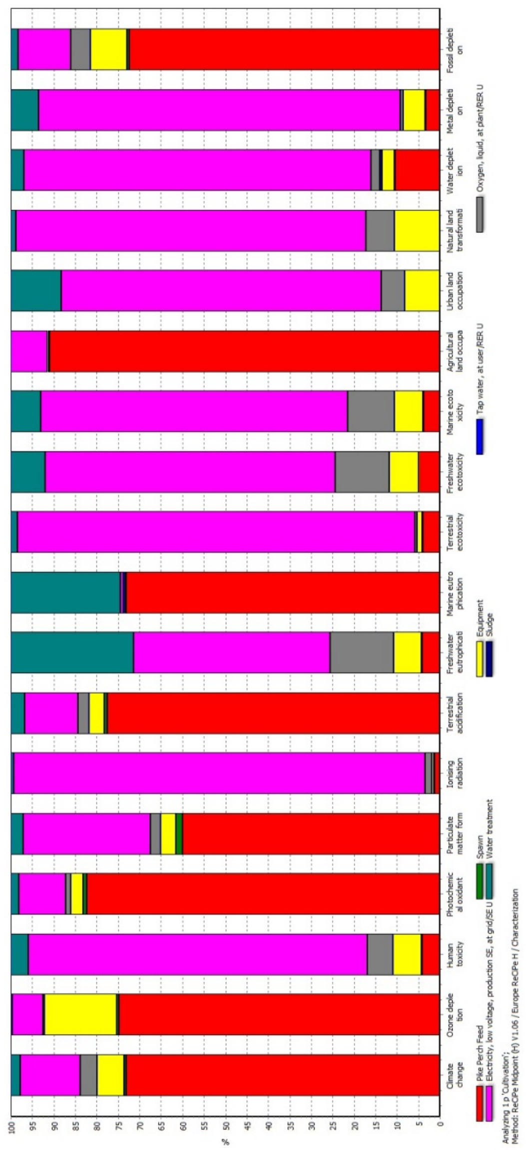

__Figure 7.__ Categorized result for cultivation process of 1 kg of fish.

Figure 8 illustrates the impacts from the different processes within cultivation compared to Europe’s reference value. The most significant categories are human toxicity, water toxicity, and water eutrophication. The graph shows that electricity and wastewater are the main impact contributors within most of the categories except from the marine eutrophication where the ammonia from fish feed is a dominating factor.

Phosphate and phosphorus cause the eutrophication; those are emitted through electricity construction infrastructure and during the waste water treatment. In the infrastructure phosphor is leaking from the sulfidic tailings as consequence of raw material mining operations. For marine eutrophication nitrogen equivalents are caused in the rape seed agriculture through fertilizers. From the normalization bars it can be concluded that human toxicity, eutrophication and water toxicity were highlighted.

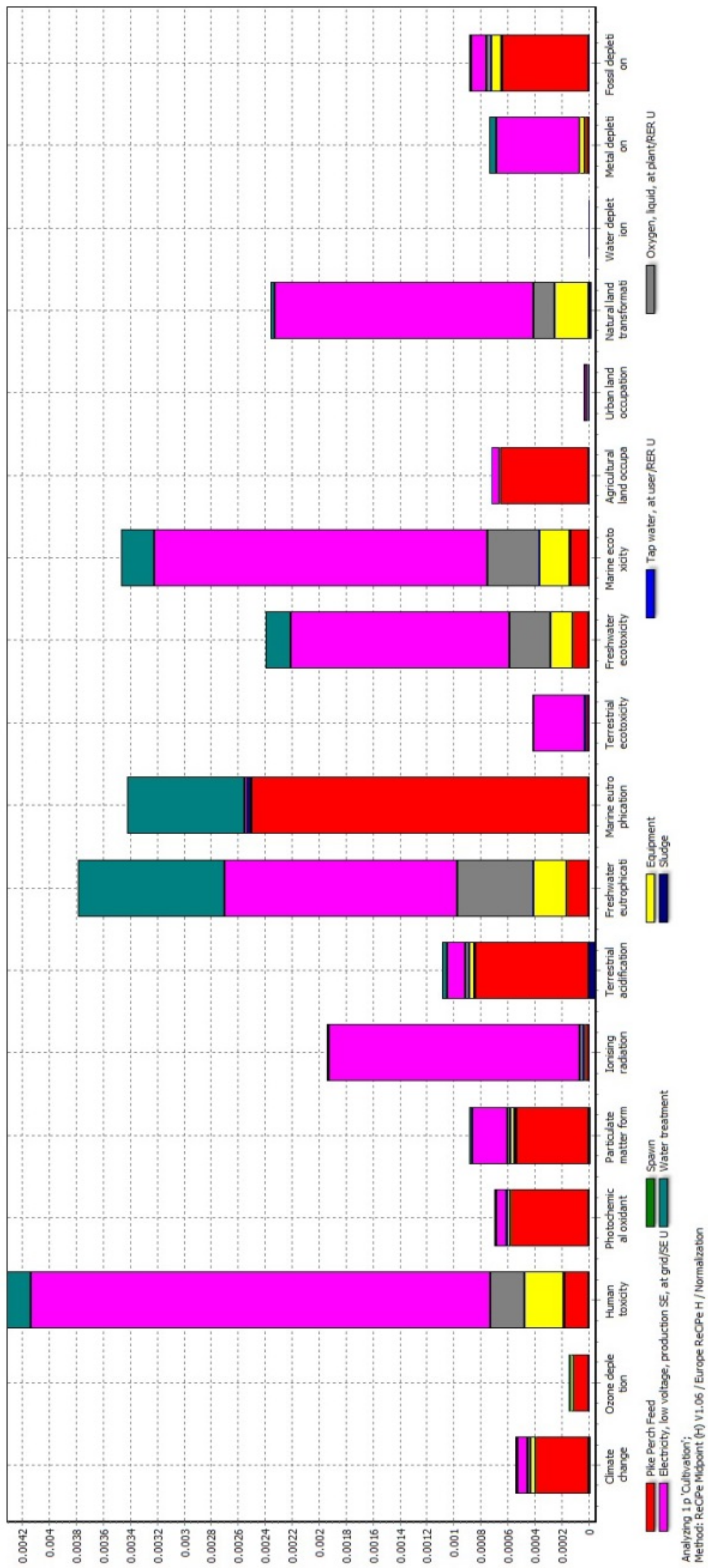

Figure 8. *Normalized result for cultivation process*

The network, see figure 9, demonstrate the distribution of $CO_2 - eqv$ for the fish cultivation. The total emission of $CO_2$for one kg of Pike Perch fillet is 15.2 kg in which 15.1 kg corresponds to the cultivation part of the LCA. In comparison 15 kg of carbon emission equals the driving distance of 87 km for a normal car (Carbon Calculator, n.d.).

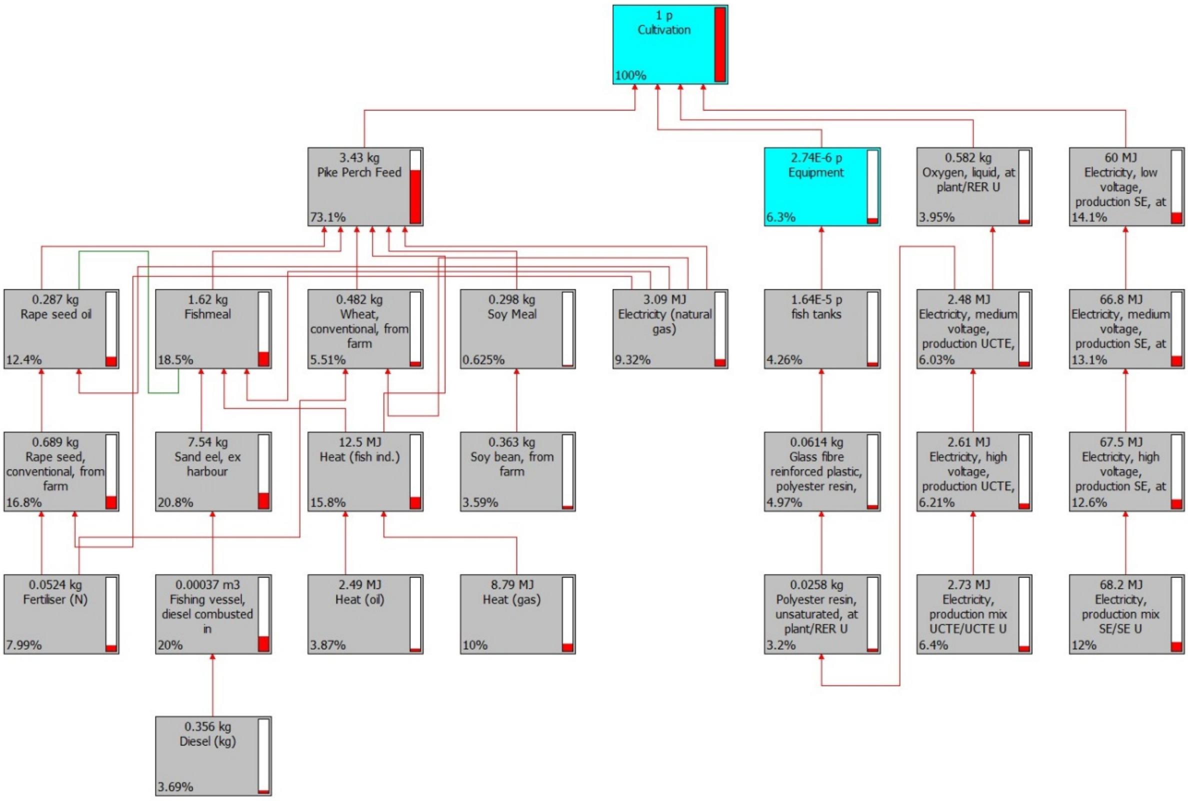

Figure 9. *Result for cultivation process CO2 equivalents*

3.2 Sensitivity analysis

As stated in figure 7 one can see that the electricity has a large impact. Compared to the European average it can be concluded that the impacts on global warming is lower when using Swedish electricity. Within the categories terrestrial eco toxicity and ionising radiation the European average have less contribution compared to the Swedish one, see figure 10. This reason for this is higher emissions of phosphorus within the toxicity and actinides within radiation.

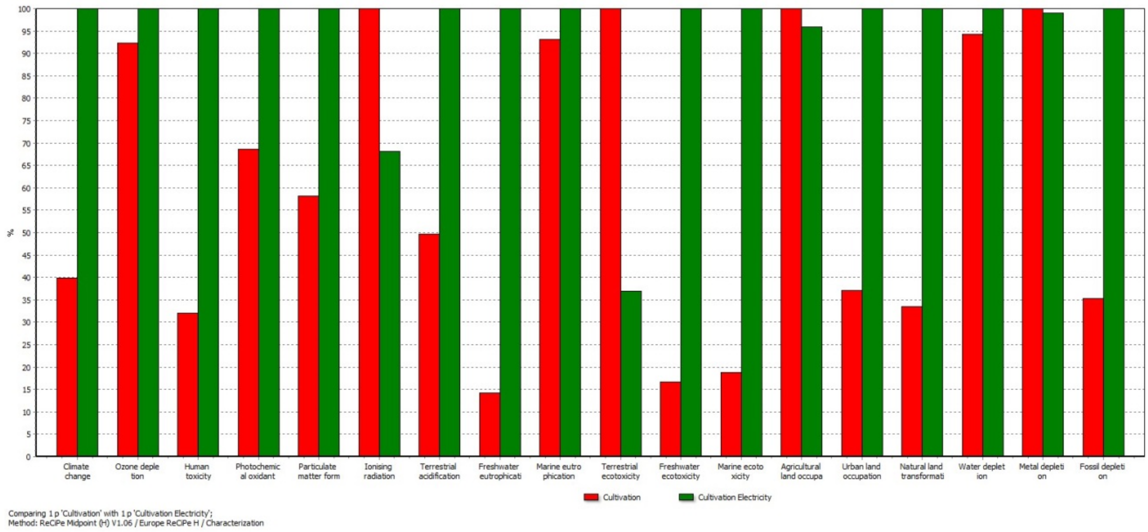

Figure 10. *Comparison for cultivation characterisation between Swedish electricity and European average.*

A comparison where the avoided burdens of biogas production from the fish waste where neglected was also made. This analyse is illustrated in figure 11. In this figure the human toxicity is decreased by its half, since no phosphorus is emitted. The terrestrial eco toxicity is also lower when the biogas process is excluded. The most significant reason for this is the reduction of phosphorus related emissions.

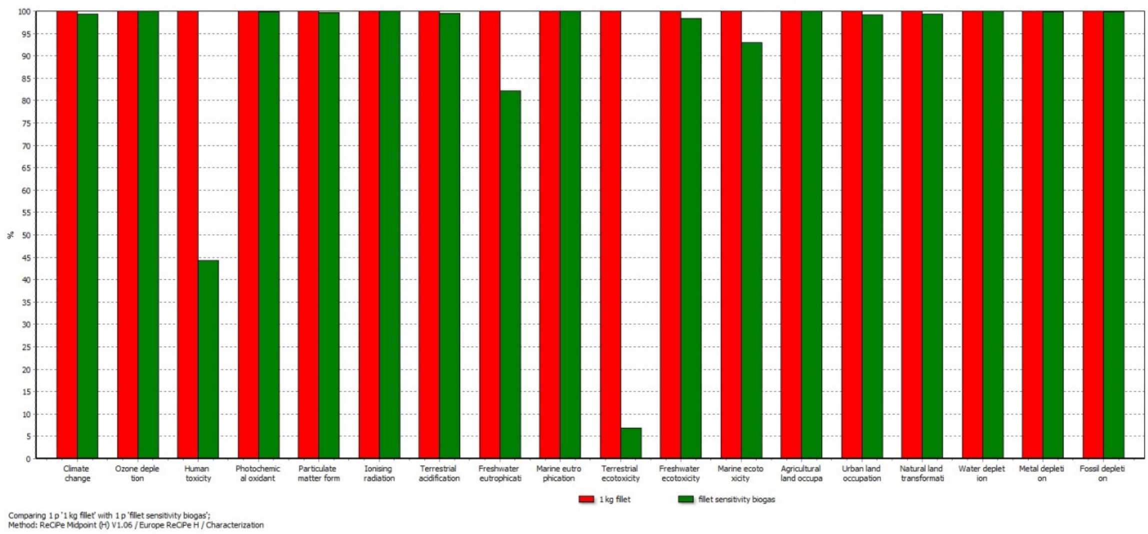

Figure 11. *Comparison for cultivation characterisation for fish waste with (red) and without biogas (green).*

In figure 12 the cultivation step for the conventional fish feed are compared to plant-based protein feed in form of peas. The main difference in the results is based on the requirements of diesel; higher for fish feed and lower for the peas. In the agricultural production of the peas butane is used which have the impact of causing toxicity. Further, the land use requirements of cultivating peas are also larger.

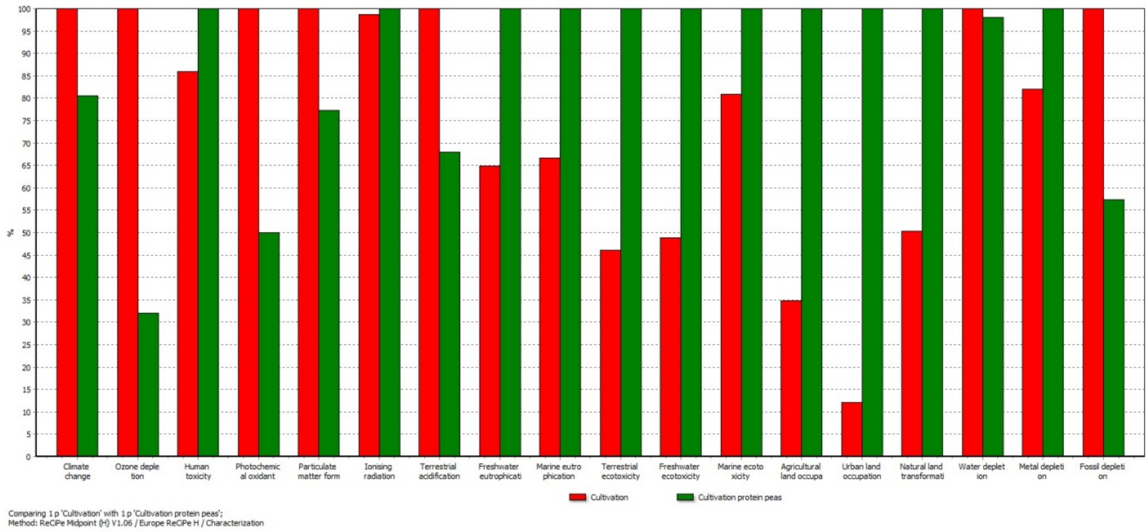

Figure 12.*Comparison for cultivation characterisation for protein feed (green) and fish feed (red).*

3.3 Discussion

Within the assembly “waste to biogas” we can see that both of the categories terrestrial eco toxicity and human toxicity are large contributing factors. When analysing these two categories is shown that phosphorus is the highest contributing factor for this. The outcomes from the sensitivity analysis comparing impact with or without biogas production shows that both human and terrestrial toxicity again are highly dependent of the phosphorus factor. Why phosphorus score high in toxicity in the ReCiPe midpoint method is not known. The phosphorous is a resource that is used on arable land as fertilizer but can cause damage to human if concentrated. This could be one reason for the high score in the human toxicity category. Another reason could be the fact that phosphorous is a contributing factor to eutrophication, which in turn cause eco toxicity.

Concerning the use of fish waste we have modelled our LCA so that all of it goes to biogas production. But is this really the best use of the waste. The waste could be used as a base of feed production later used in the production. Even more favourable is to use more of the fish as food supplements, fish broth and other livestock could be produced. In the case of an expansion the production site could choose to towards large-scale production of biogas, when the biomass increases. Another direction could be the one mentioned about feed internal feed production. Whether an internal fishmeal production, which in turn reduced the need for wild caught fish, or if biogas production is the most environmental friendly way to go is still to be investigated. One thing that is clear is the many factors involved which will affect the outcome.

In figure 12 the change to plant-based protein feed did not drastically change the impact profile, still lots of fossil fuel and larger land demand was required. Furthermore, the conducted LCA shows that the use of plant-based protein in feed means more intense use of nutrients, contributing to higher eutrophication, and larger land use compared to fishmeal based fish feed used at Ljusterö RAS. Even though the LCA clearly states advantages of using fishmeal we all agree on the controversy and big issue named overfishing. 47% of the fish feed consists of fishmeal and a large use will most certainly mean a higher overfishing than before. This, very serious, impacts could be lowered substantially if the massive amounts of discarded fish parts were refined to food supplements or used for producing fish feed. But instead regulations concerning fishing quotas create problems in this aspect. Anyway, by changing feed into plant-based protein favour the seas and if less fossil fuel and less electricity where to be used in this process we could probably find a good solution. The feed is fundamental for the impacts; other LCA-studies should be used when new food specialized for RAS plants are developed.

The data used for the LCA of the Ljusterö RAS where not site specific. The data selected from the SimaPro databases was chosen to fit the model in the best possible way according to the specifications given by Öberg (2014). The data is average and for further analysis of the fish farm, a more accurate modulation of feed would be needed.

Another factor to improve is the treatment of the sludge produced in the cultivation step. In our LCA it is now categorized as compost but without any avoided burdens. One way of utilizing the sludge could be in biogas production. If the material loops where to be closed even further the sludge could be used as an internal fertilizer and in the best case reduced by internal water cleaning from plants. By adding cultivation of vegetables as an internal cleaning process, the system could produce not only fish but also vegetables.

One big benefit of the RAS is the reduction of contaminated wastewater. This means less emission of nutrients to the i.e. Baltic Sea, which is under heavy pressure from eutrophication. By improving and maintaining high quality water treatment, investigate environmental sounder feed and utilizing the waste in the most efficient way there is a big potential in RAS and its future models for local fish supply.

3.4. Conclusions and recommendations

The results show that the oil is the main contributor to the impact indicators. The combustion of oil is driven by the fish feed production. The combustion is dominating for causing climate change, human toxicity, photo chemical oxidants, particulates and terrestrial acidification. Also, the wheat and seed agriculture from fish feed is the largest contributor to marine eutrophication. The burdens of toxicity are overrepresented by the electricity production, whereas for human toxicity it’s both electricity and biogas. Therefor the main hotspots are identified as the fish feed and electricity. The impacts on the functional unit caused by the equipment are relatively low and are therefore of lower importance relative to the flows. The fish farm could also be improved by a better waste water system.

The recommendation is to further investigate the two hotspots of electricity usage and fish feed. Alternative feed especially adapted for RAS plants and the fish species with low input of fish meal and beneficial LCA profile would put the fish production on the leading edge.

4. References

4.1. Literature

Baumann H. and Tillman A., 2004. *The Hitch Hiker's guide to LCA.* Lund: Studentlitteratur AB.

4.2. Journal articles from the web

Boissy *et al.*, 2011, *Environmental impacts of plant-based salmonid diets at feed and farm scales*, [Online] Available at: http://www.sciencedirect.com/science/article/pii/S0044848611006818 [Accessed 11 December 2014]

Carbon, n.d., *Carbon converter* [Online] *Available* at: http://carbon.to/ [Accessed 11 December 2014]

Jackson, *et al.,* 2001. *Historical Overfishing and the Recent Collapse of Costal Ecosystems.* [online] Available at: http://www.sciencemag.org/content/293/5530/629.full [Accessed 3 December 2014]

Svenskt Vattenbruk, 2014. *Fiskodling innomhus.* [Online] Available at: http://www.svensktvattenbruk.se/amnesomraden/omvattenbruk/reportagefranolikavattenbruk/fiskodlinginomhus.4.37e9ac46144f41921cde99f.html [Accessed 3 December 2014]

Queensland Government, 2014. *Recirculating aquaculture systems.* [Online] Available at: https://www.business.qld.gov.au/industry/fisheries/aquaculture/site-selection-and-production/aquaculture-production-systems/recirculating-aquaculture-system-characteristics [Accessed 3 December 2014]

ReCiPe, 2008. *Methodology*. [online] Available at: http://www.lcia-recipe.net/project-definition [Accessed 11 December 2014]

4.3. Interviews

Öberg O., 2014. *Data about RAS fish farm on Ljusterö.* [E-mail] (Personal communication, 25-27 November 2014)

Appendix I: Raw data

Appendix table 1 shows the raw data given from the fish farm. For the equipment with materials the project group calculated the outer volume minus the inner volume to get the volume of the material. That was then multiplied with the density to get the weight of the materials shown in table 1 chapter 2.2. For the data gaps for such as for thickness and height realistic values was assumed.

Equipment	Material	Size
Fish tank	Fibre glass	10 m^3 6 mm thick 1 m high
Oxygen cone	Stainless steel	500 litres
High Aquifers	Same as fish tank	
Low Aquifers	Swivel block lined with fibre glass reinforced PVC	20 m^3
Bio-filter	Same as low aquifers	
DynaSand filter	Stainless steel Sand	3 m^3
Trickling filter	Fibre glass Stainless steel	10 m^3
Pumps		4 kW
Heat Pump		No data

Appendix table 1. *Raw material data for equipment*

In appendix table 2 the raw data for inputs and outputs is presented. The timeframe of the units was recalculated to days, and then divided by 20 kg which is the amount of fish taken out each day. This gives the unit in per kg whole fish, which is shown in table 2 and 3 in chapter 2.2.

Input	Unit	Amount
Electricity	kWh/month	10 000
Water	Litre/min	6
Fish feed	Kg/h	1
Spawn	pieces/year	8000

Oxygen	Litre/min	6
Outputs		
Waste water	Litre/min	6
Sludge	Gram/h	200
Fish waste	Percent of whole fish	60 %

Appendix table 2. *Raw data inputs to the fish farm*

Appendix II: Characterized cultivation results for 1kg fish

Impact category	Unit	Total	Pike Perch Feed	Spawn	Equipment	Tap water, at user/RER U	Oxygen, liquid, at plant/RER U	Electricity, low voltage, production SE, at grid/SE U	Water treatment	Sludge
Climate change	kg CO_2 eq	5.794375	4.402961	0.02653	0.379571	0.000136	0.235114	0.850113	0.128686	-0.22874
Ozone depletion	kg CFC-11 eq	3.15E-06	2.36E-06	1.5E-08	5.32E-07	6.94E-12	1.16E-08	2.21E-07	1.27E-08	-3E-09
Human toxicity	kg 1,4-DB eq	2.551904	0.105992	0.002028	0.170937	9.89E-05	0.152441	2.020588	0.103911	-0.00409
Photochemical oxidant formation	kg NMVOC	0.036606	0.030528	0.000314	0.00104	3.65E-07	0.000491	0.004043	0.000673	-0.00048
Particulate matter formation	kg PM10 eq	0.012893	0.00791	0.000216	0.000472	2.09E-07	0.000309	0.003926	0.000374	-0.00031
Ionising radiation	kg U235 eq	12.11039	0.151425	0.004503	0.068508	8.48E-05	0.185149	11.62535	0.083431	-0.00807
Terrestrial acidification	kg SO_2 eq	0.035261	0.028788	0.000264	0.001308	5.4E-07	0.000979	0.004634	0.001175	-0.00189
Freshwater eutrophication	kg P eq	0.001566	6.52E-05	2.82E-07	0.000104	1.08E-07	0.000232	0.000719	0.000448	-3.4E-06
Marine eutrophication	kg N eq	0.034521	0.025295	0.000109	6.69E-05	3.41E-08	6.62E-05	0.000256	0.008817	-8.9E-05
Terrestrial ecotoxicity	kg 1,4-DB eq	0.003367	0.000135	3.31E-06	3.85E-05	2.68E-08	1.77E-05	0.003126	4.95E-05	-2.4E-06
Freshwater ecotoxicity	kg 1,4-DB eq	0.025984	0.001278	8.66E-06	0.001782	2.69E-06	0.00328	0.017638	0.00207	-7.6E-05
Marine ecotoxicity	kg 1,4-DB eq	0.029377	0.001127	2.51E-05	0.001946	1.99E-06	0.003244	0.021039	0.002072	-7.8E-05
Agricultural land occupation	m2a	3.250326	2.96101	0.011834	0.004119	9.41E-06	0.003039	0.273317	0.001603	-0.00461
Urban land occupation	m2a	0.013145	0	0	0.001098	6.42E-06	0.000751	0.010084	0.001596	-0.00039
Natural land transformation	m2	0.000375	0	0	4.02E-05	4.52E-08	2.52E-05	0.00031	4.62E-06	-4.5E-06
Water depletion	m3	0.092249	0.009614	9.61E-05	0.00268	0.000487	0.001909	0.074964	0.002771	-0.00027

Metal depletion	kg Fe eq	0.520848	0.017171	0.000586	0.02694	8.18E-06	0.003017	0.441058	0.033628	-0.00156
Fossil depletion	kg oil eq	1.459315	1.06181	0.006849	0.124252	3.63E-05	0.068047	0.180888	0.024221	-0.00679