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ASSESSMENT OF DANSK AKVAKULTUR SPREADSHEET SOLUTION FOR CALCULATION OF CLIMATE FOOTPRINT FOR AQUACULTURE – CONFORMITY WITH EU ENVIRONMENTAL FOOTPRINT REQUIREMENTS

The project has received support from the Danish Fisheries Authority and the European Maritime and Fisheries Fund under the Marketing Promotion Scheme.

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Den Europæiske Hav- og Fiskerifond

HAV & FISK

Made by: Bureau Veritas HSE
for Dansk Akvakultur

Date: 14 March 2022

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Requirements and scope:

Assessment of data and spreadsheet solution regarding compliance with the principles in the EU PEFCR/OEFCR guidelines for calculating carbon footprint for an aquaculture farm.

(The PEFCR covers more environmental impact categories and downstream uses as well as requirements concerning EF-study and reporting – these are not included as the scope for this assignment are compliance with the calculation method for GWP).

The assessment approach is based on guidelines, scope and methodology defined by the EU's Product Environmental Footprint (PEF) and Organisational Footprint (OEF) initiative. However, since no PEF Category Rules (PEFCR) has yet been developed for freshwater fish products, the calculations in this report are based on the framework described in the document "Product Environmental Footprint Category Rules - Guidance Version 6.3 – May 2018" (from here on referred to as the PEFCR guidance document). Additionally, the document "PEFCR – Feed for food-producing animals – Version 4.2 – February 2020" are to be used for climate contributions from compound fish feed.

- Single impact environmental assessment:
- Climate change: Global Warming Potential with and without land use change.

This report is based on the below information and input from Dansk Akvakultur, Lisbeth Jess Plesner and a site visit.

- Draft spreadsheet received 8 September 2021
- Draft model received 8 September 2021
- Publication: Opdræt af regnbueørred i Danmark, 2010
- Site visit 13 October 2021: Jedsted Mølle Dambrug (overview of RAS farm, production processes and QA with Magnus Michelsen)
- Teams meeting 30 September 2021

Objectives:

Objectives for the assessment include:

- Scoping and organisational boundaries for a generic value chain and model farm
- Requirements concerning DQR (data quality requirements)
- Use of primary and secondary data, including data gaps

- Procedure concerning ranges in GWP-values from compound fish feed due to nutritional value normalisation
- Calculations based on data in draft spreadsheet from Dansk Akvakultur

BV team:

Charlotte Thy, Lead auditor

Odyssefs Papagiannidis, LCA consultant

Freja Jeppesen, trainee in BV from Aalborg University

Contact person Dansk Akvakultur:

Lisbeth Jess Plesner

Chefkonsulent/Chief Adviser
Dansk Akvakultur
Agro Food Park 15, DK-8200 Aarhus

Mobil +45 2282 8702
e-mail: lisbeth@danskakvakultur.dk

Model information

Defining the LCA model and the underlying assumptions and relationships is the base for calculating an environmental footprint based on LCA methodology.

It was decided to use the RAS farm with 100 – 500 l water pr kg feed (former Model III1) as the underlaying generic fish farm model for the spreadsheet calculations. The model can cover all freshwater plants, including those with less technology and the ones with more extensive production capacity.

The material environmental impacts have to be captured in the model. The below model was developed in dialogue with Dansk Akvakultur and adjusted after the site visit. It has been guiding the assessment of the spreadsheet and the environmental footprint gap-analysis.

The findings are reported through the spreadsheet attached to this report which includes the changes to the original spreadsheet bringing calculations in compliance with the principles in the EU EF-methodology mentioned under scope.

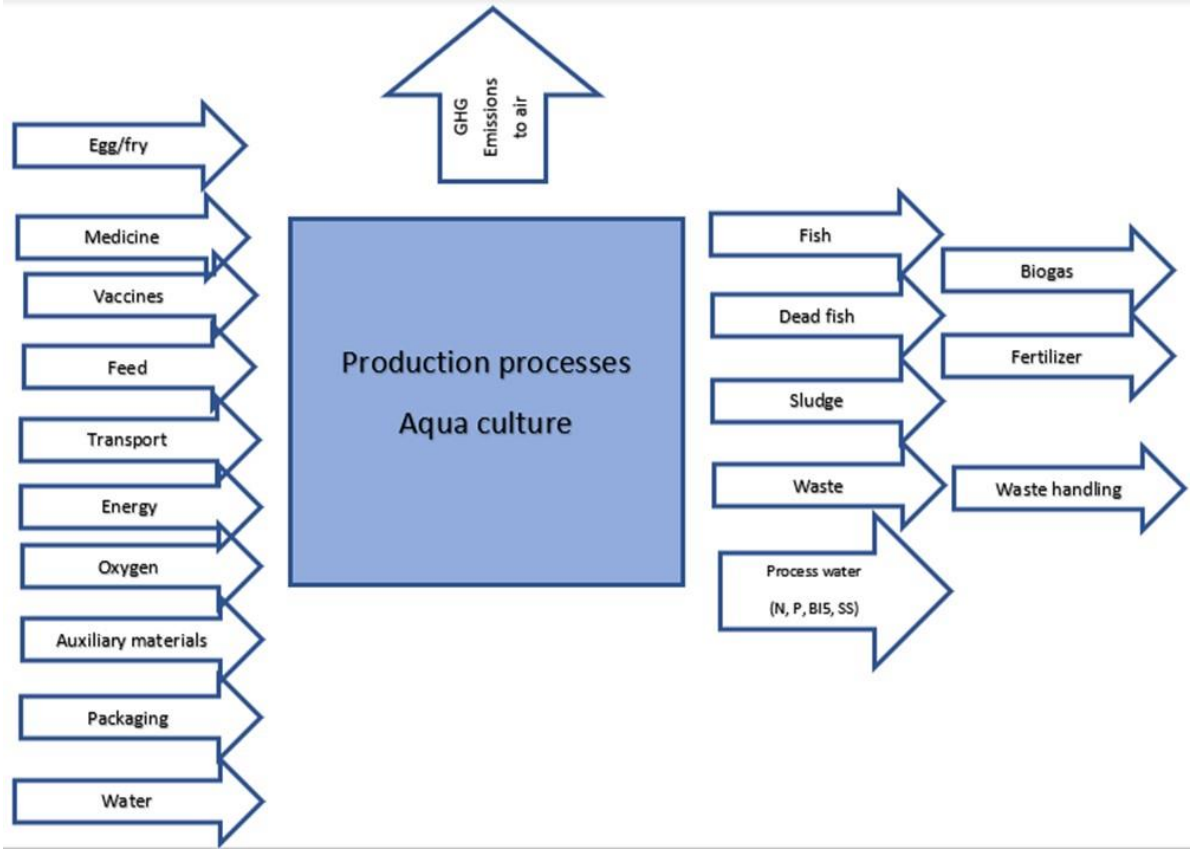

Figure 1: LCA model for fish farm

Organisational boundary: Processes operated by the fish farm contributing directly to the production of fish and the supply chain for raw material acquisition and processing hereof.

All input data from the fish farms shall be provided "per year" in the spread sheet, as this will be used to calculate the climate footprint for the fish farm. Moreover, the organizational climate footprint is used to calculate the climate footprint related to the fish farm

Scope: Aquaculture farm.

System boundary (included life cycle stages):

- Raw material acquisition and pre-processing: Production of feed, eggs and/or fry, vaccines, medicine, and other materials/products needed for the production stage and the transportation hereof to the production facility.
- Production/manufacturing: Grow out of fish at the fish farm.

This model does not include distribution or slaughtering of the produced fish due to the organisational scope.

The end of life (EOL) for waste generated during production is modelled and reported in the production stage according to the PEFCR guidance document (section 7.18). However, the Circular Footprint Formular defined by the PEFCR guidance document is not used for the calculation due to lack of data.

Assumptions to the model concerning input data for fry/fish and feed:

- the environmental footprint associated with fry/fish is given by the supplier of these based on weight ranges (see eggs and/or fry)
- the environmental footprint from fish feed is either given by the supplier of compound fish feed and is based on the Feed PEFCR, or if that is not the case, the generic values in the spreadsheet shall be applied instead

Reported impact category: Total climate change (global warming) – the sum of

1. Climate change – fossil
2. Climate change – biogenic
3. Climate change – land use and land transformation

As described in the PEFCR guidance document (section 7.9). Characterization factors from EF
3.0 method are used and the results are reporting in ton CO2-eq per

fish farm.

Data

Primary and secondary data

The PEF guidance document describes two overall data types: Primary data and secondary data.

Primary data (also called company-specific data) refers to data directly measured or collected, thereby being representative for the activities of the company. Primary data can be either site-specific, company-specific or supply chain specific. Secondary data is sourced from a third-party life-cycle inventory database or other sources. Calculation a footprint in compliance with the principles for the EU Environmental Footprint implies that the secondary datasets used have to be EF compliant.

The most used source of secondary data is the Ecoinvent database, which is EF compliant (allocation, cut-off by classification), but other sources are used in cases

where the Ecoinvent database is insufficient. This is for example data from the Danish Energy Agency or technical reports.

In the following sections, it is specified whether the data shall be **primary** or **secondary**. However, the use of primary data is encouraged since secondary data is considered more conservative and therefore less favourable for the end results of the calculation.

Raw material acquisition and pre-processing

Eggs and/or fry

The fish farm receives eggs and/or fry from other facilities. The spread sheet contains secondary data for both eggs and fry in different sizes from the database Ecoinvent v3.6, but to include eggs and/or fry in the calculation, the following primary data shall be provided:

- The amount (pcs) of eggs used yearly.
- The weight (ton) of 5-80g fry used yearly.
- The weight (ton) of 81-200g fry used yearly.
- The weight (ton) of 201-500g fry used yearly.
- The weight (ton) of 501-800g fry used yearly.

If there is any waste generated from the delivery or use of eggs and/or fry, this shall be included in the calculation as well. The BV spread sheet contains secondary data for steel, aluminium and plastic waste from the database Ecoinvent v3.6 and can be expanded to include other waste types if these are generated from the abovementioned activities. To include waste in the calculation, the following primary data shall be provided:

- Type(s) and amount (ton) of waste generated yearly.

Feed and medicine

The fish feed can be produced by different suppliers and more types of compound fish feed can be used. The feed can furthermore be delivered with or without medicine, however, the medicine is not always necessary for at the fish farm, and it is therefore important to have data on every single type of feed as the carbon footprints will vary with the formulation. The fish farm can also mix in medicine at the facility, thus requiring data on this process as well. A PEFCR has been developed for feed for food-producing animals, making it evident to use PEF data for the feed. The spread sheet contains secondary data for conventional feed without medicine from the database

Ecoinvent v3.6. No secondary data has been found for medicine and feed with medicine and it should therefore be obtained from the supplier as necessary.

To include the feed and medicine in the calculation, the following primary data shall be provided:

- The amount (ton) of feed without medicine used yearly from supplier 1
- The amount (ton) of feed with medicine used yearly from supplier 1

- The amount (ton) of feed without medicine used yearly from supplier 2
- The amount (ton) of feed with medicine used yearly from supplier 2
- The amount (ton) of medicine used yearly (used separately from the feed).

New lines must be added in the spreadsheet if more types of feed with different carbon footprints are used during the year.

If there is any waste generated from the delivery or use of feed and medicine, this shall be included in the calculation as well. The spread sheet contains secondary data for steel, aluminium, and plastic waste from the database Ecoinvent v3.6 and can be expanded to include other waste types if this is generated from the above-mentioned activities. The following primary data shall be provided:

- Type(s) and amount (ton) of waste generated yearly.

Vaccines

The fish are normally vaccinated when the fish weigh around 8 g, they are vaccinated by immersing these juvenile fish into an aquatic solution. Further fish for distribution to the sea-cage farms are revaccinated with injection right before the delivery, at weight of around 500 g. However, no secondary data has been found for vaccines and it should therefore be obtained from the supplier. The provided primary data will therefore depend on the supplier's data and use of units.

If there is any waste generated from the delivery or use of the vaccines, this shall be included in the calculation, by providing following primary data:

- Type(s) and amount (ton) of waste generated yearly.

Oxygen

Oxygen is added to the water through aeration and by adding pure oxygen. The aeration requires electricity and is therefore included in the total electricity consumption. The spread sheet contains secondary data for pure oxygen from the database Ecoinvent v3.6 and primary data for adding pure oxygen shall therefore be provided:

- The amount (ton) of oxygen used yearly.

If there is any waste generated from the delivery or use of the pure oxygen, this shall be included in the calculation, by providing following primary data:

- Type(s) and amount (ton) of waste generated yearly.

Auxiliary materials

Different auxiliary materials are used for the production, e.g. formaldehyde and hydrogen peroxide. The spread sheet contains secondary data from several different auxiliary materials from the database Ecoinvent v3.6. The following primary data shall be provided for the calculation:

- The amount (ton) used yearly for each auxiliary material.

If there is any waste generated from the delivery or use of the auxiliary materials, this shall be included in the calculation, by providing following primary data:

- Type(s) and amount (ton) of waste generated yearly.

Water

Groundwater and/or surface water is used for the production. A fish farm can be supplied by water from own drills or buy water off a water work, or a mixture of the two. The energy used for pumping and treating water from own supplies will be included in the energy inventory.

The spread sheet contains data for three situations with different types of water supply: A fish farm with its own water catchment and a fish farm supplied with water from a water work with treatment facilities, furthermore the situation where fresh water is taken in from a surface waterbody by means of gravitation is included. The following primary data shall be provided for the calculation:

- Amount (m^3) of water used yearly from a fish farm's own water catchment.
- Amount (m^3) of water supplied by a water work yearly.
- Amount (m3) of surface water (gravitation catchment).

Transport of raw materials

Transportation of raw material inputs to the fish farm shall be included in the calculation in the unit ton*km. The spread sheet contains secondary data for an unspecified lorry type, but it can be updated with more specific information if for example the size and EURO type for a means of transport is known. The datasets that describe the CO2 emissions from the eggs and fry with weight of 5-80g, 81-200g,

201-500g, 501-800g already include production and transportation to the fish farm. Therefore, following primary data shall be provided in the current spread sheet:

- The transport distance (km) of inputs to the fish farm
    - fish feed from suppliers
    - Oxygen
    - Helping agents, vaccines and medicines (not medicine feed)

- The total amount (ton) of each raw material and its packaging used in every delivery.

  The frequency of deliveries is situation-specific and the transport distance (km) can be inserted per delivery or per monthly/yearly basis for each raw material, but the total value of raw material inputs shall match with the amounts registered during one year i.e. 2020.
  It is assumed that the lorries drive also with an empty load and the calculation therefore includes two-way transportation of each raw material with a default mass utilization ratio of 64%, according to section 7.14 of PEFCR guidance 6.3 document. The utilisation ratio is calculated as the kg real load divided by the kg payload and shall be adjusted upon the use of the dataset. In case the real load is 0 kg, a real load of 1 kg shall be used to allow the calculation. This default utilisation ratio of 64% shall be used to enhance the correct comparability of results, because it includes empty return trips.

Production

Energy

Electricity consumption:

Electricity is the main supply of energy at the fish farm.

Electricity is used to power pumps, machinery and other parts of the fish farm. The spread sheet contains secondary data for the carbon footprint of a specific, Danish energy mix based on data from the 2020 electricity declaration by Energinet.dk. These data are from the energy plant (ab werk) and the spreadsheet takes this into account by adding the relevant conversion factors. To include electricity consumption in the calculation, the following primary data shall be provided:

- The amount (kWh) of electricity used yearly.

According to the PEF Guidance document, the electricity mix shall be modelled as either:

1. Supplier-specific electricity product, if available,
2. Supplier-specific total electricity mix, if available,
3. Or, as a last option, country-specific residual grid mix, consumption mix

As the spread sheet uses the first option, the accuracy of the calculation is high because the fish farm has supplied specific data from their electricity supplier.

Fuel consumption

The fish farm can use fuel for its generator (which is regularly tested) and other machinery. The spread sheet contains secondary data from three types of fuels based on data from the declaration from Energinet. To include fuel consumption in the calculation, the following primary data shall be provided:

- The type and amount (L) of fuel used yearly.

Transport of waste

Transportation of the generated waste from the fish farm to the waste handling facility shall be included in the calculation in the unit ton*km. The spread sheet contains secondary data for an unspecified lorry type, but it can be updated with more specific information if for example the size and EURO type for a means of transport is known. The datasets that describe the CO2 emissions from plastic waste, metal, feed bags and other waste already include production and transportation from the fish farm to waste handling facility. Therefore, following primary data shall be provided in the current spread sheet:

- The transport distance (km) of waste type from fish farm:
  - Transport of dead fish, sludge / fish manure to agricultural land and biogas plants
  - The total amount (ton) of waste type collected in every pick-up.

The frequency of the pick-ups is situation-specific and the transport distance (km) can be inserted per pick-up or per monthly/yearly basis for each waste type, but the total value of raw material inputs shall match with the amounts registered during one year i.e. 2020.

It is assumed that the lorries drive also with an empty load and the calculation therefore includes two-way transportation of each waste type with a default mass

utilization ratio of 64%, according to section 7.14 of PEFCR guidance 6.3 document. The utilisation ratio is calculated as the kg real load divided by the kg payload and shall be adjusted upon the use of the dataset. In case the real load is 0 kg, a real load of 1 kg shall be used to allow the calculation. This default utilisation ratio of 64% shall be used to enhance the correct comparability of results, because it includes empty return trips.

Handling of waste generated from production

Biomasses like sludge and dead fish are important to capture to get a full picture of the environmental impacts.

Sludge

The sludge from the fish farm is either used as fertilizer or sent to biogas production, where it is gasified, whereafter the remaining biomass is used as fertilizer. The utilization of the sludge results in substitution of other types of energy production and the production of inorganic fertilizer.

To include the benefits of utilizing the sludge, the following primary data shall be provided:

- The amount of sludge (ton) generated yearly.
- The amount of sludge (ton) used directly as fertilizer yearly.
- The amount of sludge (ton) sent to biogas yearly.
- The dry matter content (%) of the sludge.
- The amount (%) of N in the dry matter of the sludge.

According to Miljøstyrelsen og Rambøll, 2017, the energy gain from non-digested, thick sludge depends on the amount of dry matter, which the table below gives an overview over: **Dry matter, non-digested thick sludge (%)**	**Energy gain (kWh/ton)**
4	1.0
5	11.2

6	21.5
7	31.7
8	42.0

If the dry matter of the sludge is unknown, the energy gain is 21.5 kWh/ton wet weight according to Miljøstyrelsen og Rambøll, 2017.

It is assumed, that the sludge substitutes the most used N-fertiliser (Calcium Ammonium Nitrate (CAN)), which has a carbon footprint of 6,6 CO2-eq when the FU is 1 kg N (Mogensen et al., 2018). Moreover, the utilization percentage of sludge must be taken into account, which is 45% according to Landbrugsstyrelsen, 2019. This means that 2.2 kg sludge substitutes 1 kg CAN.

Dead fish

Fish, that die during the production, are send to biogas production. According to Miljøstyrelsen og Rambøll, 2017, the energy gain from fish industry biomass is 213 kWh/ton wet weight. To include the benefits of utilizing the dead fish for energy production, the following primary data shall be provided:

- The amount of dead fish (ton) generated yearly.

Packaging waste

Packaging from the raw materials is sorted and sent to incineration or recycling. The spread sheet contains secondary data from four waste types: steel, aluminium, plastic and other materials such as fish feed 'big bags'. If waste packaging waste is generated from the delivery and/or use of raw materials, look under the specific raw material in this document to see which primary data that shall be provided to include it in the calculations.

Excluded processes and calculation methods

The calculation approach is based on PEF and the PEF Guidance document. However, the approach differs from the PEF guidelines on the following areas:

Circular footprint formula (CFF): The calculation approach has not used CFF to calculate the waste handling process for waste packaging, as it is not possible without a PEFCR.

Capital goods: The calculation approach has not included the impacts from capital goods due to lack of data. There is a cut-off criterion on 1% concerning capital goods and evidence has not been found enabling us to assess whether the fish farm is within these criteria or not.

Greenhouse gas emissions from biofilter and plant lagunes: These processes are not included in the calculation due to lack of data, however, CO2 and other greenhouse gasses may be emitted from these processes and should therefore be included if the calculation approach is updated.

The possibility to use "green certificates" on energy is not implemented in the spreadsheet. It can be an issue for future improvements.

Data quality

The EU EF methodology requires that the data quality is calculated according to a formula and that the overall data quality is below a DQR value of 3. If this value has not met the overall requirements for data quality, then the study is not in compliance with PEF methodology.

The data quality of each dataset and the total EF study shall be calculated and reported.

Data quality ratings can be qualitative and data quality scores quantitative. The alignment of qualitative ratings and quantitative scores can be seen in table below. The qualitative ratings have a range from Poor to Very Good, while the quantitative scores have a range from 4 to 1. In this case DQR value is 3 for **Fair** rating, 2 for **Good** rating, 1 for **Very Good** rating.

DQR Quantitative Scores	DQR Qualitative Ratings
4	Poor
3	Fair
2	Good
1	Very Good

The calculation of the DQR shall be based on the following formula with 4 criteria:

$$DQR = \overline{TeR} + \overline{GR} + \overline{TiR} + \overline{P4}$$ **Equation 1**

where TeR is the Technological-Representativeness, GR is the Geographical-Representativeness, TiR is the Time-Representativeness, and P is the Precision/uncertainty. The representativeness (technological, geographical and time-related) characterises to what degree the processes and products selected are depicting the system analysed, while the precision indicates the way the data is derived and related level of uncertainty.

The scores ranging from 1 to 3 of the 4 DQR criteria when *primary* datasets are used have been accessed based on section 7.9.2 in the PEFCR Guidance Document and table 9.4.1-1 of Feed PEFCR.

The scores ranging from 1 to 3 of the 4 DQR criteria when *secondary* datasets are used have been accessed based on section 7.9.2 in the PEFCR Guidance Document and on Table 9.5.2-1 of Feed PEFCR.

A dataset that contains a mixture of plastic waste representative for Denmark was chosen to describe the plastic waste output of the system and a dataset that is representative for feed bags at their end of life was chosen to describe the feed bags with enhanced durability. The data quality of both processes is Good (TeR:2 GR:2 TiR:1 P:2 Total:1.75) and slightly above the DQR threshold score of 1.6 for specific datasets, but it is below the DQR threshold score of 3 for generic datasets. However, the DQR for the whole unit process of waste materials containing steel, aluminium, plastic and feed bags waste is 1.5, which is below the threshold value of 1.6. The Annex 1, 2, 3, 4 published in December 2021, after the project started in September 2021, has reduced the threshold value to 1.5, but the DQR of the study is also compliant with this requirement. Therefore, the data quality is considered accurate and acceptable.

The Overall DQR should be below 3 and it is 1.40, so it is compliant with the PEFCR guidance document 6.3.

As per PEFCR and OEFCR guidance document 6.3, section 7.9.2, for the company/organisation specific datasets, the DQR score should be <=1.6. (<=1.5 based on Annex 1, 2, 3, 4 of EU EF method).

Data quality requirements (the lower the score, the better)	DQR Total	DQRrmp Fish farm operation data i.e. energy use	DQRo Outbound transport i.e. from suppliers to fish farm	DQRi Inbound transport i.e. within fish farm and to customers	DQRfip Primary ingredients composition from suppliers	DQRfis Secondary ingredients composition from database
Required score without comparison	**<3**	**<=1.6**	**<=1.6**	**<3**	**<=1.6**	**<3**
Required score for comparisons	**<2**	**<=1.6**	**<=1.6**	**<3**	**<=1.6**	**<3**

The Overall DQR is **1.40**, as calculated from taking into account the 100% of processes in Dansk Akvakultur's database, so it is considered accurate and is line with the principles for EU Environmental Footprinting.

References

Product Environmental Footprint Category Rules - Guidance Version 6.3 – May 2018

PEFCR – Feed for food-producing animals – Version 4.2 – February 2020

DTU Aqua, 2010, Opdræt af regnbueørred i Danmark, 2010

Miljøstyrelsen og Rambøll, 2017, Performance benchmarking - energigevinst ved ekstern biomasse og energiindhold i energikilder

Nguyen et. al., 2011, Environmental assessment of Danish pork

Landbrugsstyrelsen, 2019, Vejledning om gødsknings- og harmoniregler

Mogensen et al., 2018, Bæredygtighedsparametre for konventionelle fodermidler til kvæg - metode og tabelværdier

Energinet.dk, 2020, https://energinet.dk/eldeklaration

Recommendations

would need to be investigated further:

- Obtaining data for emissions to air from biofilter and plant lagunes
- Green certificates and residual electricity mix on electricity
- Better values for medicine
- Better values for vaccine
- Assessment of capital goods in relation to 1% cut off criteria
- Implement new manure modelling when this is ready from the European agricultural modelling group (relevant for sludge and dead fish)
- Development of model to other types of aquaculture