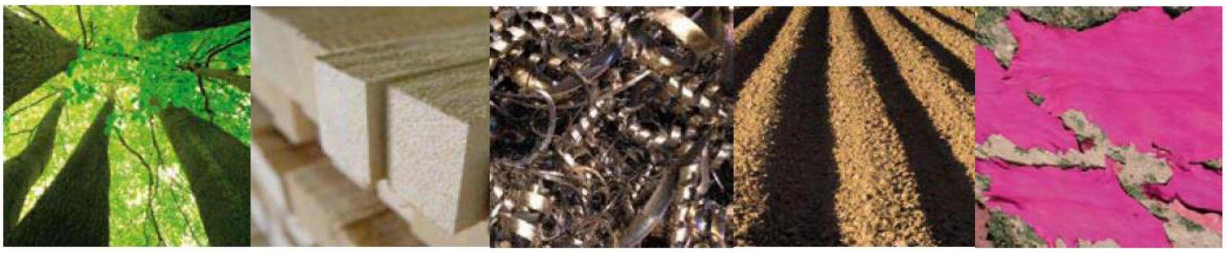


CIP Eco-innovation
Pilot and market replication projects
Call 2012

Call Identifier: CIP-EIP-Eco-Innovation-2012

Report on LCA, economic analysis and cost-benefits analysis
D2.5 Part 1

Ecoponics
Contract ECO/12/332783/SI2.656985

Reporting Date
05/08/2015

Project coordinator: Dr. Ragnheidur Thorarinsdottir
WP2-leader: Fernando Sustaeta
Project website: http://aquaponics.is/ecoponics/

CONTENT

REPORT ON LCA

GOAL AND SCOPE OF THE LIFE CYCLE ASSESSMENT

The current study shows the results of the Life Cycle Assessment of the BREEN aquaponics technology system operation in the demonstration plant located in Hondarribia (spain), for obtaining 2000kg of fish (Tilapia), 515kg of vegetables and 875kg of Vermicompost. The system boundaries include the necessary materials for the infrastructure, energy use, water use and fish feed.

The quantity and the toxicity of the materials have been taken into account as well as the environmental impact of the operation and activities related, for the operation of an average 12 months period.

The functional unit is the benchmark to which all the life cycle data of the process are referenced, so it is used to normalize the considered inputs, outputs and environmental impacts of the studied product system. The Functional Unit of the study is "12 months of the BREEN aquaponics technology system operation in the demonstration plant located in Hondarribia (spain), for obtaining 2000kg of fish (Tilapia), 515kg of vegetables and 875kg of Vermicompost".

So the LCA study has a "Craddle to gate" approach, as it includes the extraction and production of raw material for the infrastructure, the extraction and production of feed for the fish growth and the production and consumption of energy for the system operation.

The objective of the study has been done to identify the environmental impact of this new technology and for evaluating its sustainability against traditional technologies, so it is intended for internal use by BREEN S.L and the ECOPONICS European financed project partners, in order to ascertain the main significant environmental aspects of the process.

The LCA study has been developed with the collaboration of the expert LCA consultancy company IK INGENIERIA www.ik-ingenieria.com

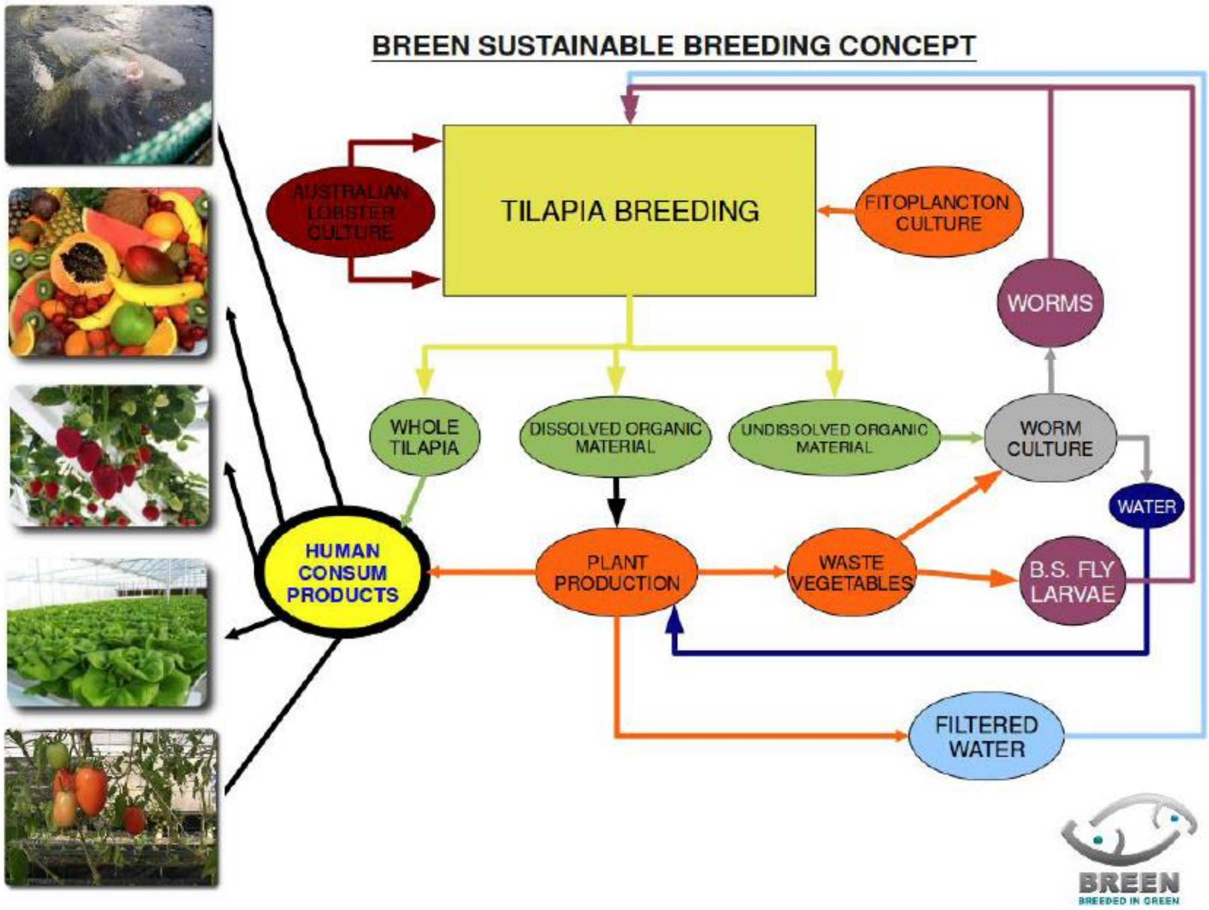
SYSTEM BOUNDARIES: BREEN AQUAPONICS TECHNOLOGY

Aquaponics is defined as a sustainable system combining traditional aquaculture with hydroponics, where plants are cultivated in water. Effluents from the aquaculture are used as nutrients for the plants in the hydroponics, thus creating a symbiotic natural environment with maximum utilization of all raw materials and waste. The cleansed water from the plants are then recycled back to the fish tanks.

Aquaponics systems have three points of important control and production units: The fish tanks, the filters with nitrifying microorganisms transforming organic matter into in-organic nutrients for plants and thirdly the plant production itself. The system contains water with production of herbs, vegetables or fruits.

The challenge however for a modern Bio-food producer engaged in aquaponics is to maximize overall economic output by synchronizing the various biological growth periods and optimums of fish, plants and microorganisms into a stable and balanced biomass production system.

The figure below shows a flowchart related to the closed-loop commercial aquaponics solution based on the BREEN technology.

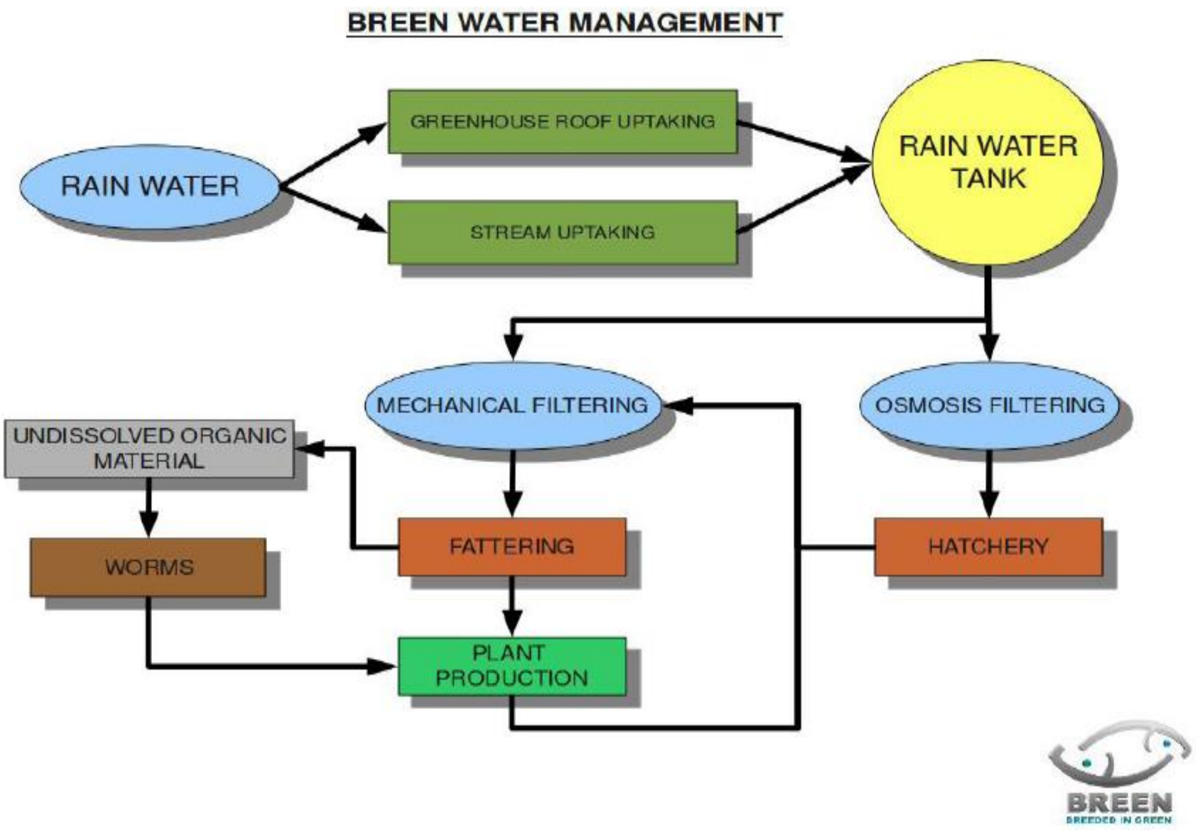


Simplified system boundaries of the study

The innovation aspect of this BREEN technology is to focus on environmentally friendly production and total utilization of all resources, introducing and implementing viable closed-loop aquaponics production systems: the production is 100% based on sustainable ingredients, non-synthetic fertilizers are used for the plant production, no effluent water or waste leaves the plant (there is none fresh water consumption as the system feeds by100% rain water input) and there is no waste generation as the generated sludge is re-circulated to a vermiculture for obtaining compost (Vermicompost).

Water management

The water used in the system is rain water collected in a tank under the green houses. 9m3 of water is added per month, an average of 10% of the total water in the system every week. No CO2 is added to the plant system and no waste water is taken out from the system.



Water management in the BREEN technology process

The total water volume of the pilot system was 20 m3, with 9m3 of fish farming water volume and a maximun stocking density of 46 kg/m3 during the test period.

Fish feeding and growth

The fish has been fed during this period with Biomar, Efico Alfa 845F fish feed. The daily feeding is on average 3% of the fish biomass with a particle size of 1.5 mm, 3.0 mm and 4.5 mm depending on the fish size 4-15g, 15-60g, 60-400g.

		Temperature (°C)								
Fish size (g)	Feed – pellet size (mm)	17	19	21	23	25	27	29	31	33
8 - 15	1.9	1.77	2.66	3.40	4.25	4.67	7.64	6.78	3.50	1.54
15 - 25	1.9	1.63	2.53	3.26	4.07	4.26	7.41	6.48	3.35	1.47
25 - 35	3.0	1.58	2.38	3.16	3.95	4.17	7.10	6.39	3.25	1.43
35 - 60	3.0	1.34	2.06	2.68	3.34	3.62	5.53	4.99	2.75	1.21
60 - 100	4.5	1.23	1.85	2.46	3.08	3.31	3.63	3.20	2.53	1.12
100 - 160	4.5	1.06	1.58	2.11	2.64	2.84	2.91	2.74	2.17	0.96
160 300	4.5	0.90	1.35	1.80	2.25	2.42	2.48	2.33	1.85	0.81
300 - 400	4.5	0.76	1.14	1.52	1.90	2.04	2.09	1.97	1.56	0.69

Feeding indicative (kg feed per day for 100 kg of fish)

Automatic feeding system.

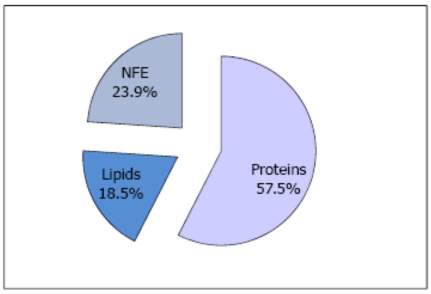
The total 12 month period fish production is about 2.000 kg.

The production of fish feed is quite relevant contributor to fresh water eutrophication and ozone layer destruction. This is due to nitrogen based fertilizers used in the agricultural production of the main ingredients such as rapeseed, wheat and soy and the use of fishmeal from fisheries industry.

The manufacturer of the feed used in this demonstration plant (BIOMAR – Efico alpla Tilapia Feed) is proprietary of the specific formula of the feed, and only generic information about the characteristics and nutritional chart was provided.

Product characteristics: 4.5 mm

Digestible energy distribution

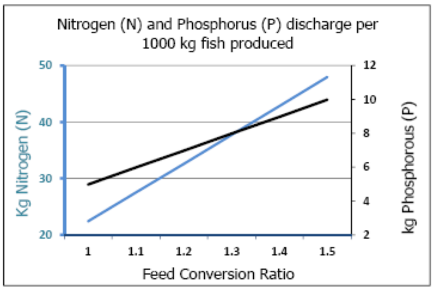


Composition

Soya cake
Wheat
Sunflower cake
Rapeseed meal
Fish meal
Fish oil
Vegetable oil
Vitamins and minerals

GMO below 0.9%

Ecological declaration



Therefore a theorical feed formulation was created, using data from the LCAFOOD LCA database (www.lcafood.dk) and starting from the "fishmeal production" and "trout feed production", adapting them to the specific characteristics of the Biomar feed using ECOINVENT database. The ingredients were adjusted to create a tilapia feed for 57% protein.

Tilapia feed 57% protein	
Soya Cake	2,27%
Wheat	35,71%
Sunflower	18,82%
Rapeseed meal	13,19%
Fish Meal	20,00%
Fish Oil	5,00%
Vegetable Oil	5,00%

Percent main ingredients formula Tilapia feed used in the LCA study

Filtering system

The filter system includes a compartment settling tank system and sand filters of the type Kripsol BL640, separating the solid particles from the water. It is crucial in a aquaponics system to have an effective filtering system, removing the solid organic matter, even small particles. The first compartment filters approximately 80% of the solids, the second one filters 20% and nitrification takes place in the third, eliminating the ammonia through biological filtration. When the water reach the fourth tank it is ready to be pumped through the system again.

Sand filters

Sludge and Vermiculture

The sludge is not treated as pollutant matter but as organic matter rich in nutrients that are used for another type of culture using a biological sewage treatment plant. The biological treatment plant at BREEN demonstration plant is based on a mixed culture of bacteria and earthworms. The sludge from the filter system is moved to the system and used for vermiculture and Vermicompost obtaining. This Vermicompost is a storable material that serves as fertilizer for plants and the excess of worms serves as extra protein intake for the Tilapia.

Vermiculture: biological sewage treatment plant at BREEN demonstration plant

The total 12 month period Vermicompost production is about 875 kg.

Vegetable production

The organic waste from the fish supports 250 m2 of vegetable production with lettuce, tomatoes, peppers and aromatic herbs. The total 12 month period vegetable production is about 515 kg.

Aquaponic vegetable growth systems

Energy consumption

The BREEN demonstration plant uses electricity for the control systems (feed automatic system, water pumps, temperature and climatic control lights…).
There is also a direct use of renewable energy and waste heat from a cogeneration system next to the demonstration plant. This energy is used to control the fish containers temperature in aprox 25C° for optimal growth rates.

ELECTRICITY CONSUMPTION	kW	h/day	Quantity	kWh/ day	kWh /year
2 external water pumps (0,25HP)	0,184	9	2	3,31	1.207,24
2 external water pumps (0,25HP)	0,184	1,5	2	0,55	201,21
2 internal water pumps (0,33HP)	0,243	24	2	11,64	4.249,48
2 submarine water pumps (450W)	0,45	2	2	1,80	657,00
3 submarine water pumps (450W)	0,45	24	3	32,40	11.826,00
LED fotoperíod lights SUMMER	0,35	4	1	1,40	255,50
LED fotoperíod lights WINTER	0,35	0	1	0,00	0,00
Computers (labour day)	0,75	8	1	6,00	1.902,00
Profilux Control	0,15	24	1	3,60	1.314,00
Aerator	0,09	24	1	2,16	788,40
					22.400,82

The total 12 month period electricity consumption is about 22.400 kwh.

Control

The automatic control of all the main process parameters is important, minimizing risk in the production system, controlling the water quality and obtaining optimal utilization of all resources. In order to follow the water quality parameters, Breen has installed a Profilux surveillance system purchased from the German company GLH (https://www.aquariumcomputer.com/en-GB/products-shop/profilux-controllers). With this system the company controls all the factory automation, the feeding, the photoperiod and the volume of water in the tanks. Moreover, the most important water quality parameters are measured; pH, temperature, conductivity, Redox, the level of oxygen, humidity, and ambient temperature.

LCA SOFTWARE, DATABASE AND ENVIRONMENTAL IMPACT METHODOLOGY

LCAManager LCA software has been used for the LCA study. LCAmanager is a practical tool for Life Cycle Assessment (LCA) and for supporting eco-innovation in companies. It allows to quantify and communicate with indicators the environmental performance of industrial products and processes, and the achieved environmental improvements in its re-design and eco-innovation. LCAmanager is fully compatible with Ecoinvent database, which is the main database that has been used in this study.

Ecoinvent is one of the world's leading database of consistent and transparent, up-to-date Life Cycle Inventory (LCI) data. With over 10.000 LCI datasets in the areas of energy supply, agriculture, transport, biofuels and biomaterials, bulk and specialty chemicals, construction materials, packaging materials, basic and precious metals, metals processing, ICT and electronics, dairy, wood, and waste treatment, ecoinvent is one of the most comprehensive international LCI databases. LCI datasets are based on industrial data and have been compiled by internationally renowned research institutes and LCA consultants, and all datasets are reviewed by at least three LCA experts prior to the storage of the datasets in the database.

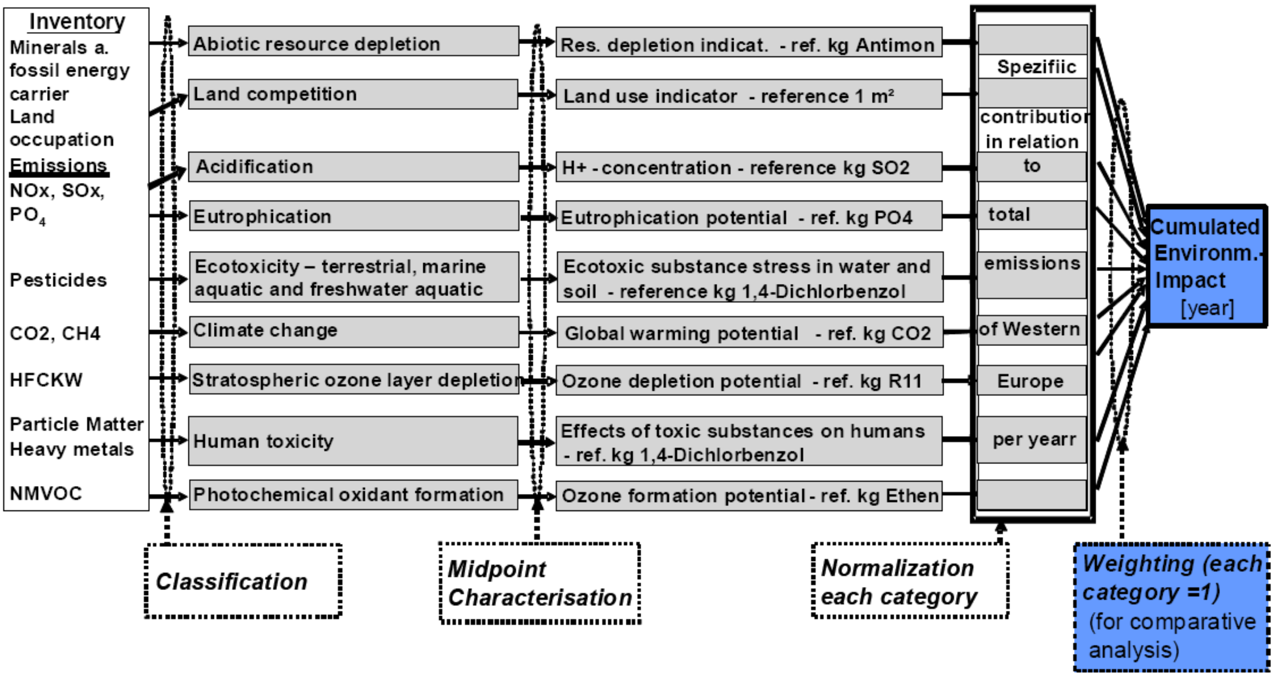
More information: http://www.ecoinvent.org

CML

The CML LCA methodology is developed by the CML (Center of Environmental Science of Leiden University). The CML has a long tradition in the methodological development of LCA and the CML methodology is the most widely-used and often considered the most complete methodology. It uses primarily European data to derive its impact factors.

CML is an impact assessment method which restricts quantitative modelling to early stages in the cause-effect chain to limit uncertainties. It groups the LCI results into midpoint categories, according to themes; these themes are common mechanisms (e.g. climate change) or groupings (e.g. ecotoxicity). A Microsoft Excel spreadsheet with characterisation factors for more than 1700 different flows can be downloaded from the CML website. The characterisation factors are updated when new knowledge on substance level is available.

The general structure and used impact categories of the CML method (baseline) are showed bellow:



Each impact category is characterized by a midpoint indicator which uses a defined reference substance in order to quantify the impact of a classified emission in relation to the reference substance. Usually the CML method is finished after the normalization of each impact category whereby the result shows an environmental profile of different 11 baseline impact categories. The step of normalization calculates the specific magnitude of impact category result of the investigated system in relation to reference information. In the case of CML method as spatial reference value the total emission of Western Europe per year is selected.

In the present study, the following environmental aspects has been selected, as they are considered the most relevant and representative for the scope of the study:

CATEGORY	NAME	UNIT
Climate change	GWP 100a	kg CO_2-Eq
Acidification potential	Average European	kg SO_2-Eq
Freshwater eutrophication potential	generic	kg PO_4-Eq
Human toxicity	HTP 20a - global	kg 1,4-DCB-Eq
Depletion of abiotic resources	depletion of abiotic resources	kg antimony-Eq
Stratospheric ozone depletion	ODP 20a	kg CFC-11-Eq

More information:

http://cml.leiden.edu/research/industrialecology/researchprojects/finished/new-dutch-lca-guide.html

RECIPE

ReCiPe was created by the Dutch National Institute for Public Health and the Environment (RIVM), the CML (Center of Environmental Science of Leiden University), PRé Consultants, and Radboud Universiteit Nijmegen.

The publication in 1992 of the first CML LCA methodology marked a breakthrough in the scientific foundation of LCA. A further Dutch innovation was the development of Eco-indicator 95 and its later version, Eco-indicator 99, by PRé Consultants. The CML and the Eco-indicator LCA methodologies are widely accepted methodologies. However, they are based on different points of departure:

- The CML uses the approach that has been proposed as the baseline method for characterisation (Handbook on LCA) – the midpoint approach.
- The Eco-indicator 99 focuses on the interpretation of results and uses the endpoint approach.

In 2000, a special session that focussed on understanding the strengths and weaknesses of the midpoint and end-point methods was organised in Brighton. At the end of this session, the 50 LCA experts who had participated jointly concluded that it would be desirable to have a common framework in which both midpoint and endpoint indicators can be used. This consensus became the basis of the ReCiPe method. The project aimed at harmonizing the CML midpoint and the PRé Ecoindicator99 endpoint approach into a single, consistent methodology.

The primary objective of the ReCiPe method, is to transform the long list of Life Cycle Inventory results into a limited number of environmental indicator scores. These indicator scores express the relative severity on an environmental impact category.

ReCiPe determines environmental indicators at two levels:

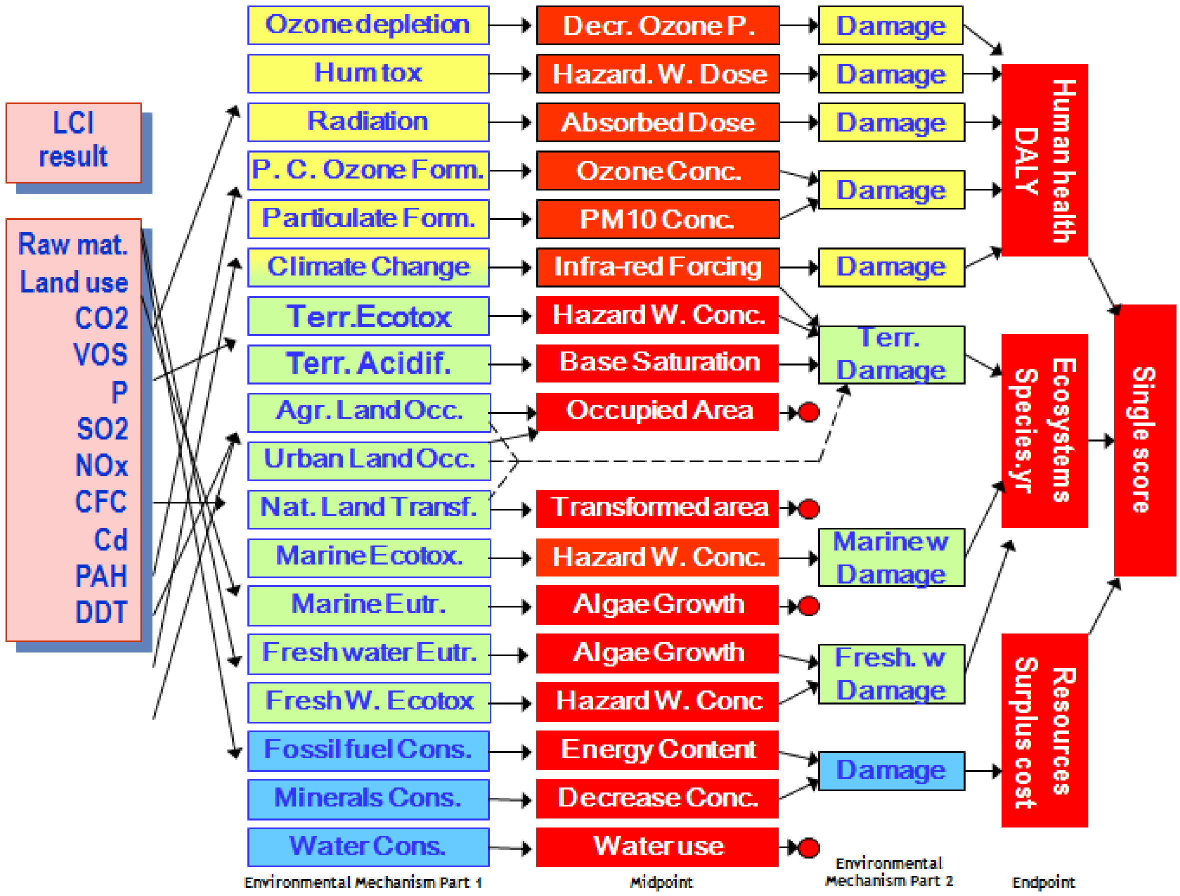
- Eighteen midpoint indicators
- Three endpoint indicators

ReCiPe uses an environmental mechanism as the basis for the modelling. An environmental mechanism can be seen as a series of effects that together can create a certain level of damage to for instance, human health or ecosystems. The indicators at the endpoint level are intended to facilitate easier interpretation and they have a more understandable meaning.

The objective is that each user can choose at which level it wants to have the result:

- Eighteen robust midpoints, but not easy to interpret
- Three easy to understand ,but more uncertain, endpoints:
    - Damage to Human health
    - Damage to ecosystems
    - Damage to resource availability
- A single final value score that represents the overall impact of the selected Life Cycle.

The figure below provides the overall structure of the method:



Relationship between LCI parameters (left), midpoint indicator (middle) and endpoint indicator (right) in ReCiPe 2008.

In the present study, the single final value score that represents the overall impact of the selected system is considered.

More information: www.lcia-recipe.net

LIFE CYCLE INVENTORY

The inventory of materials and weights amortized for the 12 months time boundary of the demonstration process are listed below. The Hondarribia demonstration plant has been operating during 4 years. During this time, data regarding system input/outputs (energy and consumables) has been gathered. These life cycle input and outputs were classified by category and material in terms of environmental impact contribution.

The following has been included in the study:

- Extraction and production of raw material for the infrastructure
- Extraction and production of feed for the fish growth
- Production and consumption of electricity for the system operation

The following has not been included in the study:

- Transportation from tier 1 (direct) suppliers to the demonstration plant location.
- Suppliers packaging
- Sand filters, water pumps, thermostats, control units, feeders… building materials and electronic equipment, as they are considered capital goods that will be reused for other purposes after the demonstration plant operation.
- Renewable energy and waste heat from the cogeneration system allocation to the system under study.
- Final products packaging
- Final products transportation to the user

Products leaving the system: Products and co-products

PRODUCTION IN 12 MONTH OPERATING		
FISH	Tilapia	**2.000 kg**
VEGETABLES	768 lettuce (300gr/lettuce)=230kg 250kg tomatoes 2kg Basil 3kg Parsley 20kg Chilli pepper 10kg Pepper	**515 kg**
VERMICOMPOST	From 988kg/year of sludge, 1,25m3 of vermicompost is obtained (700 kg/m3)	**875 kg**

Inputs/outputs to the system

LIFE CYCLE INVENTORY			Allocation for the temporal boundary (12 month)	LIFE CYCLE INVENTORY FOR 12month operating
INFRAESTRUCTURE MATERIALS				
PVC Pipes	260m of PVC tubes, with diameters between 20/90mm, and water control PVC items	737,63 kg	1/4	**184,41 kg**
PP Pipes	500m of heating PP tubes	80,4 kg	1/4	**20,10 kg**
Glass Fibre Containers	Construction material for the fish growbeds water tanks	15,81 kg	1/4	**3,95 kg**
Expanded Clay	2m3 of two dimensional expanded clay, for vegetable growbeds	1.120 kg	1/4	**280,00 kg**
Steel	Construction material	100 kg	1/4	**25,00 kg**
PE Film	Construction material	50 kg	1/4	**12,50 kg**
Wood	Construction material	0,36 m3	1/4	**0,09 m3**
Cooper	Plumbing items	1 kg	1/4	**0,25 kg**
PC	PC Cellular cover for the fish growbeds	22,95 kg	1/4	**5,74 kg**
PE	PE floating Rafts for vegetable growbeds	216 kg	1/4	**4,00 kg**
PROCCESS CONSUMABLES				
Electricity	-	22.400kwh/year	1/1	**22.400 kwh**
Heat	Used to control the fish containers temperature. As there is a direct use of renewable energy and waste heat from a cogeneration system next to the demonstration plant, no allocation has been made to this system within the scope of this LCA study (this heat enters the system "environmental burden free").	0 MJ/year	1/1	**0 MJ**
Feed	-	3.000 kg/year	1/1	**3.000 kg**
WASTE				
Sludge	100% of the sludge is converted into compost in the vermiculture system, so no waste is generated outside the system	988 kg/year	1/1	**0 kg**

LCA RESULTS

The results of this study showed the environmental impact associated with the BREEN Aquaponics technology system operation in the demonstration plant located in Hondarribia (spain), during an average 12 months period:

BREEN PROCESS 12 months	Global Warming kg CO2 eq.	Acidification kg SO2 eq.	Fresh Water Eutrophication kg PO4 eq.	Ozone layer destruction kg CFC-11 eq.	Human Toxicity kg 1,4-DCB eq.	Abiotic resource deployment kg Antimony eq.	ReCiPe Endpoint Points
	6.383,41	51,76	21,22	1,95E-04	2.263,71	42,44	870,88
INFRAESTRUCTURE	*641,67*	*2,44*	*0,52*	*1,47E-05*	*379,44*	*6,88*	*84,10*
PVC Pipes	370,34	0,99	0,16	5,75E-07	24,01	4,29	44,46
PP Pipes	39,85	0,12	0,01	9,99E-09	0,18	0,65	6,07
Glass Fiber Containers	10,41	0,06	0,02	1,24E-06	34,62	0,08	1,13
Expanded Clay	91,70	0,66	0,06	9,81E-06	39,42	0,61	9,52
Steel	43,89	0,17	0,10	2,25E-06	165,03	0,36	5,06
PE Film	24,36	0,08	0,01	8,22E-09	0,13	0,42	3,79
Wood	7,85	0,04	0,02	6,81E-07	3,44	0,06	7,08
Cooper	0,79	0,14	0,14	6,99E-08	112,04	0,01	1,73
PC Cellular cover	44,70	0,14	0,01	1,08E-08	0,52	0,29	4,07
PE floating Rafts	7,79	0,03	0,00	2,63E-09	0,04	0,13	1,21
CONSUMABLES	*5.741,74*	*49,33*	*20,70*	*1,80E-04*	*1.884,27*	*35,55*	*786,77*
Electricity	4.372,55	40,65	7,83	6,66E-05	1.166,49	30,13	416,48
Fish Feed	1.369,19	8,67	12,87	1,14E-04	717,78	5,42	370,30

BREEN PROCESS 12 months	Global Warming kg CO2 eq.	Acidification kg SO2 eq.	Fresh Water Eutrophication kg PO4 eq.	Ozone layer destruction kg CFC-11 eq.	Human Toxicity kg 1,4-DCB eq.	Abiotic resource deployment kg Antimony eq.	ReCiPe Endpoint Points
	100%	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
INFRAESTRUCTURE	10%	5%	2%	8%	17%	16%	10%
PVC Pipes	6%	2%	1%	0%	1%	10%	5%
PP Pipes	1%	0%	0%	0%	0%	2%	1%
Glass Fiber Containers	0%	0%	0%	1%	2%	0%	0%
Expanded Clay	1%	1%	0%	5%	2%	1%	1%
Steel	1%	0%	0%	1%	7%	1%	1%
PE Film	0%	0%	0%	0%	0%	1%	0%
Wood	0%	0%	0%	0%	0%	0%	1%
Cooper	0%	0%	1%	0%	5%	0%	0%
PC Cellular cover	1%	0%	0%	0%	0%	1%	0%
PE floating Rafts	0%	0%	0%	0%	0%	0%	0%

CONSUMABLES	90%	95%	98%	92%	83%	84%	90%
Electricity	68%	79%	37%	34%	52%	71%	48%
Fish Feed	21%	17%	61%	58%	32%	13%	43%

The provisions of the electricity mix in Spain and the fish feed contributed to 68% and 21% respectively for the Global warming potential, for a total of 90%, while infrastructure material impacts about 10%. The feed and electricity mix categories also contributed to over 90% impact significance in regards the overall environmental impact, represented by recipe.

The production of fish feed is quite relevant contributor to fresh water eutrophication and ozone layer destruction. This is due to nitrogen based fertilizers used in the agricultural production of the main ingredients such as rapeseed, wheat and soy and the use of fishmeal from fisheries industry.

There is therefore potential for environmental impact reduction by:

- Reducing electricity consumption
- Increasing renewable energy sources
- Optimizing consumption of fish feed

Advantages of BREEN aquaponics system for minimizing water use and nutrient discharge to the environment have been shown. However, there is opportunity for improvement in the feed by using natural feed alternatives such as organic and vegetal natural ingredients replacing fishmeal and fishoil from fisheries industry.

Net Zero water use due to the recirculation of water and use of 100% rain water may also be considered to strengthen the environmental performance assessment in comparison with traditional aquiculture systems, which is generally known to use 70% of global fresh water for operation of the system.

A breakdown of co-product mass allocation of impacts apportioned to the functional unit is shown bellow. The production weights: 2.000 kg of fish, 515 kg of vegetables, and 875 kg of vermicompost, were reported to be 59%, 15,2%, and 25,8%, respectively, of the net impact categories.

ENVIRONMENTAL IMPACT MASS ALLOCATION	TOTAL	Fish 59%	Vegetables 15,2%	Vermicompost 25,8%	>>	1kg Fish	1kg Vegetables	1kg Vermicompost
Global Warming kg CO2 eq.	6.383,41	3.766,21	572,46	147,70	>>	1,88	1,11	0,15
Acidification kg SO2 eq.	51,76	30,54	4,64	1,20	>>	0,02	0,01	0,00
Fresh Water Eutrophication kg PO4 eq.	21,22	12,52	1,90	0,49	>>	0,01	0,00	0,00
Ozone layer destruction kg CFC-11 eq.	1,95E-04	0,00	0,00	0,00	>>	5,76E-08	3,40E-08	4,57E-09
Human Toxicity kg 1,4-DCB eq.	2.263,71	1.335,59	203,01	52,38	>>	0,67	0,39	0,05
Abiotic resource deployment kg Antimonio eq.	42,44	25,04	3,81	0,98	>>	0,01	0,01	0,00
ReCiPe Endpoint (H,A) Points	870,88	513,82	78,10	20,15	>>	0,26	0,15	0,02
Direct Electricity consumption	22.400,00	13216,00	2.008,83	518,28	>>	6,61	3,90	0,52

This allocation shows that 1kg of fish production by the BREEN aquaponic Technology produces 1,88 kg CO2 eq. and consumes 6,61 kwh of direct electricity.

In the case of vegetables and vermicompost, this results are 1,11 kg CO2 eq and 0,15 kg CO2 eq respectively, and 3,9 kwh and 0,52 kwh respectively.

To further compare the difference allocation models that could be applied to this study, economic pricing data for fish, vegetables and vermicompost are discussed briefly.

Price analysis for the BREEN aquaponic Technology products showed a total of 9.887,50€ worth of fish, vegetables and vermicompost were produced based on current market price (www.mercamadrid.es , www.mercasa.es). Net tilapia product was worth 8.420€ (4,21€/kg), net vegetables was worth 1.030€ (2€/kg) and net vermicompost was worth 437,50€ (0,5€/kg).

This allocation method indicates 85,2% of net impacts are attributed to fish, 10,4% to vegetables and 4.4% to vermicompost.

ENVIRONMENTAL IMPACT ECONOMIC ALLOCATION	TOTAL	Fish 85,2%	Vegetables 10,4%	Vermicompost 4,4,%	>>	1kg Fish	1kg Vegetables	1kg Vermicompost
Global Warming kg CO2 eq.	6.383,41	5.438,67	663,87	280,87	>>	2,72	1,29	0,28
Acidification kg SO2 eq.	51,76	44,10	5,38	2,28	>>	0,02	0,01	0,00
Fresh Water Eutrophication kg PO4 eq.	21,22	18,08	2,21	0,93	>>	0,01	0,00	0,00
Ozone layer destruction kg CFC-11 eq.	1,95E-04	0,00	0,00	0,00	>>	8,31E-08	3,94E-08	8,69E-09
Human Toxicity kg 1,4-DCB eq.	2.263,71	1.928,68	235,43	99,60	>>	0,96	0,46	0,10

Abiotic resource deployment kg Antimonio eq.	42,44	36,16	4,41	1,87	>>	0,02	0,01	0,00
ReCiPe Endpoint (H,A) Points	870,88	741,99	90,57	38,32	>>	0,37	0,18	0,04
Direct Electricity consumption	22.400,00	19.084,80	2329,60	985,60	>>	9,54	4,52	1,00

This allocation shows that 1kg of fish production by the BREEN aquaponic Technology produces 2,72 kg CO2 eq. and consumes 9,54 kwh of direct electricity, from the point of view of an economic aspect allocation.

In the case of vegetables and vermicompost, this results are 1,29 kg CO2 eq and 0,28 kg CO2 eq respectively, and 4,52 kwh and 1 kwh respectively.

It is clear to see how controversial allocation modeling can be when comparing LCA results in a mass allocation and in an economic allocation. For example, fish resulted in 59% mass allocation vs 85,2% economic allocation. This variation helps us to better understand the environmental profile of the process and to fulfill a more detailed interpretation.

Finally, to guarantee the coherence and representativeness of the LCA results, and for checking the sustainability of the BREEN technology process, a comparison of other aquaculture systems performance is important. Note that systems being compared used the mass allocation method.

COMPARATIVE CHART FISH PRODUCTION (mass allocation)	Source	Global Warming kg CO2 eq./kg fish	Direct Electricity consumption kwh/kg fish
BREEN AQUAPONIC TECHNOLOGY	This LCA study	1,88	6,61
TILAPIA AQUAPONICS IN THAILAND	Mark Hindelang et al 2015	1,35	16,28
RAINBOW TROUT Flow through (FT) growth	D'Orbcastel, et al 2009	2,02	13,40
RAINBOW TROUT Water Recirculating Aquaculture System (RAS)	D'Orbcastel, et al 2009	2,04	17,55
RAINBOW TROUT Flow through (FT) growth	Aubin et al, 2009	2,75	9,75
SEABASS Net Pen System growth	Aubin et al, 2009	3,60	-
TURBOT Water Recirculating Aquaculture System (RAS)	Aubin et al, 2009	6,02	22,60
ATLANTIC SALMON Net Pen System growth	Ayer and Tyedmers, 2009	2,08	-

The aquaponics system uses less energy for operating and produces comparable or less global warming emisions than other systems.

Due to the heavy reliance on pumping and water treatment technologies, the principal operational cost associated with RAS is energy use. Energy consumption in RAS has been studied extensively (Aubin et al. 2009; Ayer and Tyedmers 2009; Roque d´Orbcastel et al. 2009; Jerbi et al. 2012) and the conclusions of these studies indicate that RAS are much more energy intensive than other aquaculture production systems. For example, RAS have energy requirements of 17.55 to 22.6 kWh/kg fish as compared to traditional flow-through systems (FTS) that require between 9.75 and 13.4 kWh/kg fish (Ayer and Tyedmers 2009; Roque d´Orbcastel et al. 2009).

Another consideration worth taking into account is that energy demands and associated impacts can change drastically based on the region, due to the energy sources for the energy production mix (for example, France uses nuclear power which produces low CO2 emissions and provides a cleaner generation under the perspective of Global warming, despite its dangerous impact for the radioactive waste management, while Norway produces much of their energy using hydropower plants having this way a very much cleaner electricity mix). In this case, the region of energy production and use affects the impact analysis. An aquaponics system is generally more sustainable in the tropics because it has a modest infrastructure burden and there are no requirements for heating.

Additionally, this study established the boundary of the aquaponics system in an urban environment. It did not take into account any transportation for the output products. When comparing a consumer's purchase of grocery store fish and vegetables, there would be packaging, handling, refrigeration, and transportation based emissions that are not taken into account in this study.

Anyway, taken into account the scope and boundaries of the selected LCA studies for comparison, and regardless the mentioned considerations, the comparison is considered reliable and coherent, so we could conclude that the sustainability of the BREEN technology process has been proved.

CONCLUSIONS

The results of this study showed the sustainability of the BREEN Aquaponics technology system operation, thanks to the development of a Life Cycle Analysis study and the interpretation of the environmental profile results. The aquaponics system is based on environmental benefits and resource efficiency in a life-cycle approach, being the main benefits:

- Direct use of renewable energy and waste heat from a cogeneration system next to the demonstration plant.
- Water consumption reduction due to more effective recirculation and use of rain-water.

- No pesticides nor hormones are used in the production system and thus no dangerous substances are present. The system is closed-loop and all nutrients are fully utilized. No synthetic fertilizers are used. By implementing healthy eco-systems with polyculture even the input of phosphate, Fe, K and Ca can be excluded.
- No direct green house gas emissions. The CO2 from the fish is used by the plants and by utilizing renewable energy sources and waste heat from cogeneration plants the CO2 from energy production is not increased by the aquaponics. The extra CO2 supplied for the plants in the greenhouses will be kept to a minimum. CO2 emissions from the fish production will be reduced with 100% due to utilization in the horticulture section. Dynamic climate control utilizing the aquaculture tanks as a heating buffer during night is estimated to save up to 6 months of heating costs in the greenhouse further reducing CO2 emissions. Local food production and utilization of local raw materials will minimize transportation and thus further lower CO2 emissions.
- The air quality is improved by the plant production.
- The EcoPonics system is a zero waste system as all materials are fully used in an optimum way. The rest organic materials are used by red worms that are kept in the nutrient cycle and used as high quality proteins and/or used as fertilizers by the Vermicompost. Nitrifying bacteria helps keeping a healthy system.
- Overall symbiotic effects are estimated to generate cost savings between 15-20% in both the aqua- and horticulture section

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ANNEX I: SOME DEFINITIONS

- Global warming/Climate change: It is related to the emissions of greenhouse gases into the atmosphere. The model characterization has been developed by the Intergovernmental Panel of Experts on Climate Change (IPPC), who have developed the corresponding factors for the characterization. These factors are expressed as global warming potential with a time horizon of 100 years (GWP100), in carbon dioxide Kg / Kg of emissions. The geographic scope of this indicator is a global scale.
- Acidification: Acidifying substances cause a wide range of impacts on soil, groundwater and surface water, etc. The acidification potential (AP) for the emissions into the atmosphere is calculated adapted with the model RAINS10, describing the destination and deposition of the acidifying substances. The indicator is expressed in Kg of SO2 eq. / Kg of emissions. The period of time is unlimited and the geographical scale varies between local and continental.
- Fresh Water Eutrophication: It includes all the effects resulting from excessive levels of nutrients in the environment caused by emissions to the air, water and soil. The eutrophication potential (NP) is based on the procedure from Heijungs (1992) and it is expressed in Kg of PO4 eq. / Kg of emissions. The destination and the exposure are not included. The time period is unlimited and the geographical scale varies between local and continental.
- Ozone layer depletion: Due to the ozone layer depletion, a greater fraction of UV radiation can reach the Earth's surface. This can have harmful effects on human health, animal health, terrestrial and aquatic ecosystems, biochemical cycles and on materials. The characterization of this model has been developed by the World Meteorological Organization (WMO) and defines the potential of ozone depletion for different gases, measured in Kg CFC-11 equivalent / Kg of emissions. The geographical scope of this indicator is a global scale, and the time period is unlimited.
- Human toxicity: The emission of some substances (such as heavy metals) can have impacts on human health. Assessments of toxicity are based on tolerable concentrations in air, water, air quality guidelines, tolerable daily intake and acceptable daily intake for human toxicity. Characterisation factors are calculated using USES-LCA which describes fate, exposure and effects of toxic substances for an 20 year time horizon. For each toxic substance HTPs are expressed using the reference unit, kg 1,4-dichlorobenzene (1,4-DB) equivalent.
- Abiotic depletion: It is related to the extraction of minerals and fossil fuels. Its value is determined by the values measured before in Kg of antimony eq. / extraction Kg, based on the concentration of the reserves and the disaccumulation rate. The geographic scope of this indicator is a global scale.

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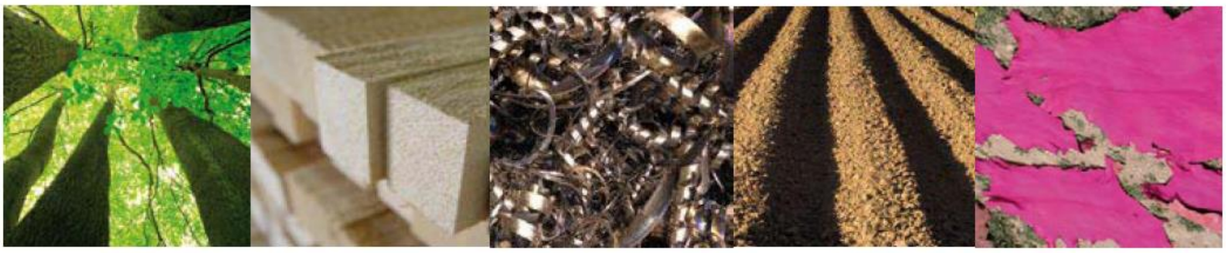

CIP Eco-innovation
Pilot and market replication projects
Call 2012

Call Identifier: CIP-EIP-Eco-Innovation-2012

Report on LCA, economic analysis and cost-benefits analysis
D2.5 Part 2

Ecoponics
Contract ECO/12/332783/SI2.656985

Reporting Date
30/07/2016

Project coordinator: Dr. Ragnheidur Thorarinsdottir
WP2-leader: Fernando Sustaeta
Project website: http://aquaponics.is/ecoponics/

ECONOMIC FINANCIAL STUDY OF THE EXPLOITATION OF BREEN

Cost of the facilities of fattening, hatchery and aquaponics filter plant

Detail	***Total Economic Assessment in Euros***	***2014***	***2015***
Adequacy of the facilities for placement of tanks and culture systems	120,000	50%	50%
Tanks of culture of concrete with waterproofing	130,000	50%	50%
Breen aquaculture production system	190,000	50%	50%
Ancillary installations	50,000	50%	50%
External biological filter system	35,000	50%	50%
Mixed system of heat source	190,000	50%	50%

Breen aquaponics production system	90,000	50%	50%
Interpretation center	90,000	50%	50%
First year wages / salary	105,000	50%	50%
Total	**1,000,000**		

VAT not included

Amortization

Detail	***Time of depreciation in years***	***Cost amortization annual***
Adequacy of facilities for the placing tanks and farming systems	20	6,000
Cultivation of concrete tanks with waterproofing	20	11,500
Aquaculture production system BREEN	10	39,000
Attached facilities	10	15,000
External biological wastewater treatment plant	10	3,500 *
Mixed system of heat source	10	19,000
Aquaponic production system BREEN	10	9,000 *
Total to pay annually in the part aquaculture		**€90,500**
Total to pay annually in the part vegetable		**€12,500**

*The comments marked with * refer to depreciation of the plant part.*

Cost of annual depreciation per kg of Tilapia for a production of 75 MT in its aquaculture (first phase) = €1.2

Cost of annual depreciation per unit for production of 250,000 units in the vegetable part = €0.05

Costs of aquaculture production and plant

Several fixed expenses (GFV)	
Administrative, 1 person full time	12,000 €/ year
Commercial, 1 person full time	8,000 €/ year + sales
Distribution costs and various	10,000 €/ year
Total	**35,000 €/ year**
GFV per kg of Tilapia	**€0.28 /kg**

Calculation of cost of production of 1 kg of Tilapia

CT = cost kg of Tilapia uncharged aquaponics staff

CPk = staff costs per kg of Tilapia uncharged aquaponics staff

CE = energy cost Cal = cost Tilapia FRY

FC = Conversion Factor = 1.5 in Tilapia

FC = amount of food necessary to get 1 kg of Tilapia ICC = cost of 1 kg of feed

ICC = € 0.5

Time until first harvest = 12 months

Costs of amortization = € 1.2

Amortization costs = CAmo

<u>Cost of feed per kg of Tilapia</u>

CAli = cost of feed for 1 kg of Tilapia

CAli = FC x weight of Tilapia in kgs x CPi

CAli = 1.5 x 1 x 0.5 = €0.75

CAli = €0.75

<u>Personal aquaculture production costs</u>

6 technicians of aquaculture production

ERCP = Personal aquaculture production costs.

ERCP = 5 people = € 12,000/month

ERCP = 12,000

PT = production of Tilapia = 10,800 kg/month

ERCP = staff of aquaculture production costs per kg of Tilapia. ERCP = 12,000 / 10,800 = €1.11 /mes/kg of Tilapia

ERCP = 1.11 €/ month/kg of Tilapia

<u>Energy costs (extrapolation of consumption calculated on pilot test)</u>

Thermal costs average annual thermal solar mixed system / biomass

Character = € 0.2 / kg/tilapia/month

Electrical costs = 12,500 KW/month = €1500 / month

CEle = 1500 x 12 = 18,000 €/ year in electrical costs

CEle = EC / total annual production of Tilapia

CEle = 18,000 / 125,000 = €0.14 electric cost per kg of Tilapia.

<u>Costs of FRY</u>

Fi = having own hatchery, FRY costs would be included in staff costs mentioned above. **CAle = 0**

Total = CAli + ERCP + CElec + character + Camo + GFV = 0.75 + 1.11 + 0.14 + 0.2 + 1.2 + 0.28

= €3.68

Production costs from the first harvests by adjusting the biomass per 50 kg/m^3 m^3 up to 70 kg/m^3 can be improved and the Conversion Factor from the continuous improvement that exists in the field of aquaculture feed can be improved.

Improving the FC they improve and reduce harvesting time and the cost of power.

In addition to the above production costs should take into account the administrative and commercial as well as transport and distribution costs.

Revenue

Income derived from an aquaponic production as mentioned, lets you take the market tilapia and vegetables. As mentioned above, estimates established for nurseries Zumeta project intends to have a volume of annual production of Tilapia **75 Tm** plant (first phase) and about **250,000 units** .

Whole Tilapia selling price estimate is that it will be around the **4.5 €.**

If the total volume of aquaculture production is 75 metric tons/year (first phase), **€4.5 / kg**, gives us a volume of revenues of **€337,500** Tilapia.

As mentioned above in the section on costs, the cost of production per kg of Tilapia is **€3.68** whereupon the cost of annual production will be of **€276,000**. Whereupon, part aquaculture can conclude that profits could estimate of

61,500 €/ year.

For the vegetable part, estimated that each plant produced unit could have a value of **0.30€** in the market, so the revenues obtained by the plant production of **250,000 units** would be an amount of **€ 75,000.**

Vegetable production costs are estimated at approximately **€55,000** in relation to staff costs (3 persons), energy costs, of material and depreciation, so that the benefit obtained by the plant part would amount to **€ 20,000 per year.**

We must not forget that the vegetable part is actually a tool for basic filtration system with which their greater effectiveness lies in that precisely the cultivated product being the second important variable in the equation.

Summary of revenue costs and profits year:

	Income	**Costs**	**Benefits**
Aquaculture production	**€337,500**	**€276,000**	**€61,500**
Plant production	**€75,000**	**€55,000**	**€20,000**

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