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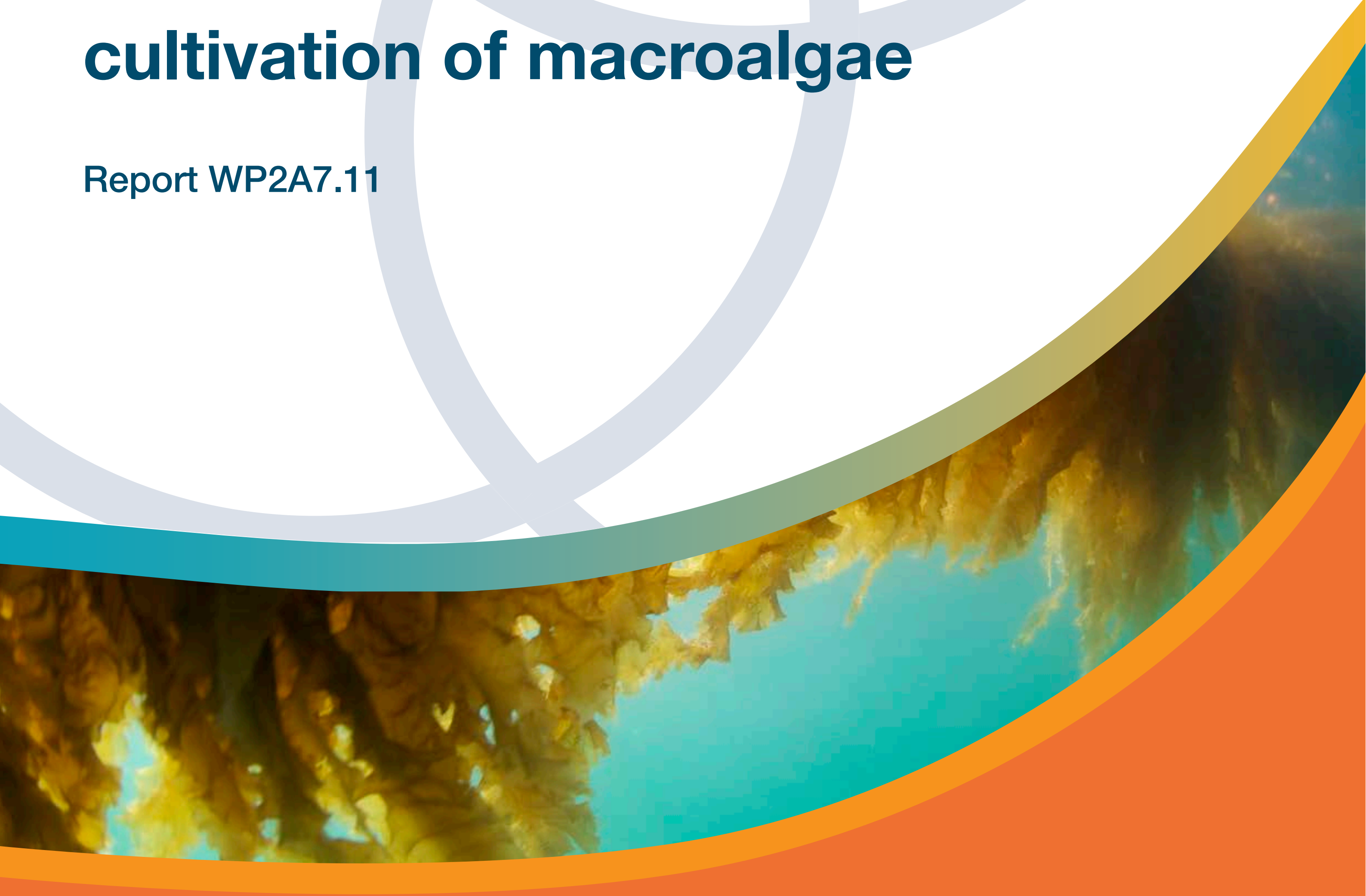
An economic model for offshore cultivation of macroalgae

Report WP2A7.11



Energetic Algae ('EnAlgae')

Project no. 215G

Public Output

Output WP2A7.11 – An economic model for offshore cultivation of macroalgae

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1 Introduction

Algae biomass is considered as a potential non-fossil source of raw materials to produce fuel, feed, chemicals and materials. For this purpose microalgae as well as macroalgae can be used, and in this report we focus on the latter. More than 99% of the world production of aquatic plants is produced in Asia (FAO 2012, Table 1). From the remaining 1% about 4% is cultivated in Europe. Important European countries with commercial seaweed cultivation are Denmark, Ireland and France. Depending on their pigmentation seaweed species are commonly grouped in brown, red and green seaweeds.

Table 1: World aquatic plant production in 2012 (FAO, 2013).

Continent	Production (*1,000 tons)
Asia	23,581
Africa	161
Oceania	22
Europe	7
America	5
Total	*23,776*

Within the European project Energetic Algae work has been carried out to describe the production costs and identify the variables that have most effect in determining future cost prices so that research can be focussed on these issues. This has been done by making use of pilots for microalgae as well as macroalgae within the EnAlgae consortium and by describing the process in excel models that have been shared and discussed with stakeholders active in the field of commercial algae production. The expectation is that this transparency and interaction will lead to an increase of the learning curve to make algae production more cheap and thus supplying more markets.

As basis for the macroalgae model, we used the report "Cultivating *Laminaria digitata*. Aquaculture explained". (Edwards & Watson, 2011). Together with the input from the participating partners in the project (Ireland: National University of Ireland Galway, UK-Northern Ireland: Queens University Belfast, UK-Wales: Swansea University, France: Centre d'Etude et de Valorisation des Algues) the model was constructed. The model is set up in such a way that all parameters that are affecting the economic results can be adjusted by the user to her/his specific situation.

With regard to the scope of the model the following restrictions have been taken into account:

- The model is focusing on the production of brown kelps that are grown in the wintertime.
- The model is confined to offshore growing of macroalgae on longlines being the most common growing system in the participating countries.
- Land based cultivation systems (in tanks) as described for the production of *Palmaria palmata* (Werner & Dring, 2011) are excluded.
- The model does not contain a module that simulates the growth of the seaweed based on climatic data (e.g. light, temperature).

The model, available on the www.enalgae.eu web site, is freely available to all those interested in macro-algae production and use.

2 Economic model for macroalgae production

2.1 Introduction

The Excel model contains several worksheets (Figure 1). In the sheets “Input_main” and “Input_background” the different input parameters can be set. For most parameters default values are given. A distinction is made between parameters that are expected to be varied most frequently by users (sheet “Input_main”, e.g. size of the farm, yields, prices) and more detailed parameters that are not likely to be changed frequently by the users (sheet “Input_background”). However, as mentioned above, the user is able to adjust all parameters according to their needs. In the sheet “Regions” region/country dependent figures are given (e.g. yields, labour price, electricity price).

Based on the input data, the economic parameters are calculated in the sheet “Calculations”. The sheets “Hatchery”, “Labour_hatchery” and “Labour_sea” are used for background calculations.

A summary of the results of the economic calculations is given in the sheet “Economics_sum”. In this sheet also the built up of the cost price is given (table and graph).

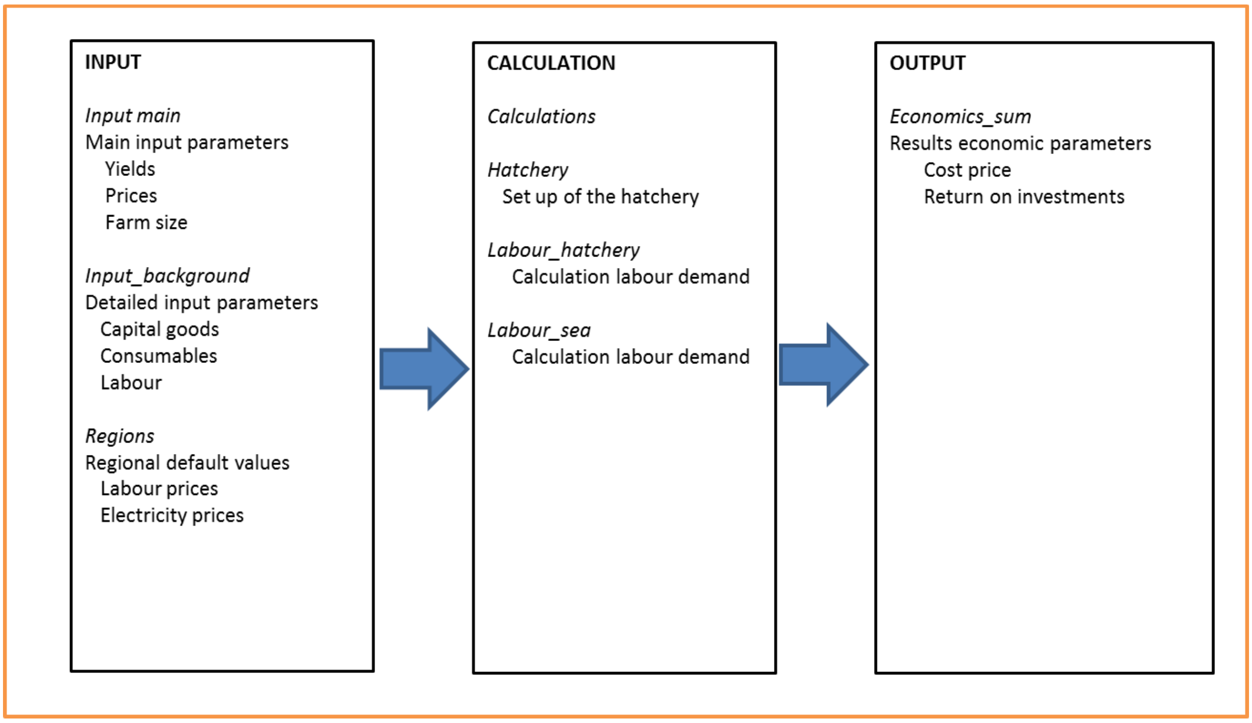

Figure 1: *Set up of the economic model macro-algae.*

2.2 Modelling the seaweed farm

This section describes the way the seaweed farm is modelled. First, a short description is given of the growth cycle of brown kelps and, subsequently, the different parts of the seaweed farm are elaborated.

2.2.1 Growth cycle brown kelps in North Western Europe

In Figure 2 the growth cycle of the brown kelp *Laminaria digitata* is given. The cycle starts when reproductive material (sorus) is developing. From the sorus male and female haploid zoospores are released. After germination they develop to gametophytes that produce eggs and spermatozoids. After fertilisation a diploid sporophyte develops. In a natural environment the sporophytes settle on a suitable substrate (e.g. rocks) and grow out after which the cycle starts again.

On a seaweed farm the production of juvenile sporophytes from zoospores (released from collected ripe seaweed material) is done in a hatchery taking about 3-5 months. Subsequently, the sporophytes are seeded on a culture string that is deployed along line-systems at sea in late autumn. After growing out for 5-6 months the biomass is harvested in the spring.

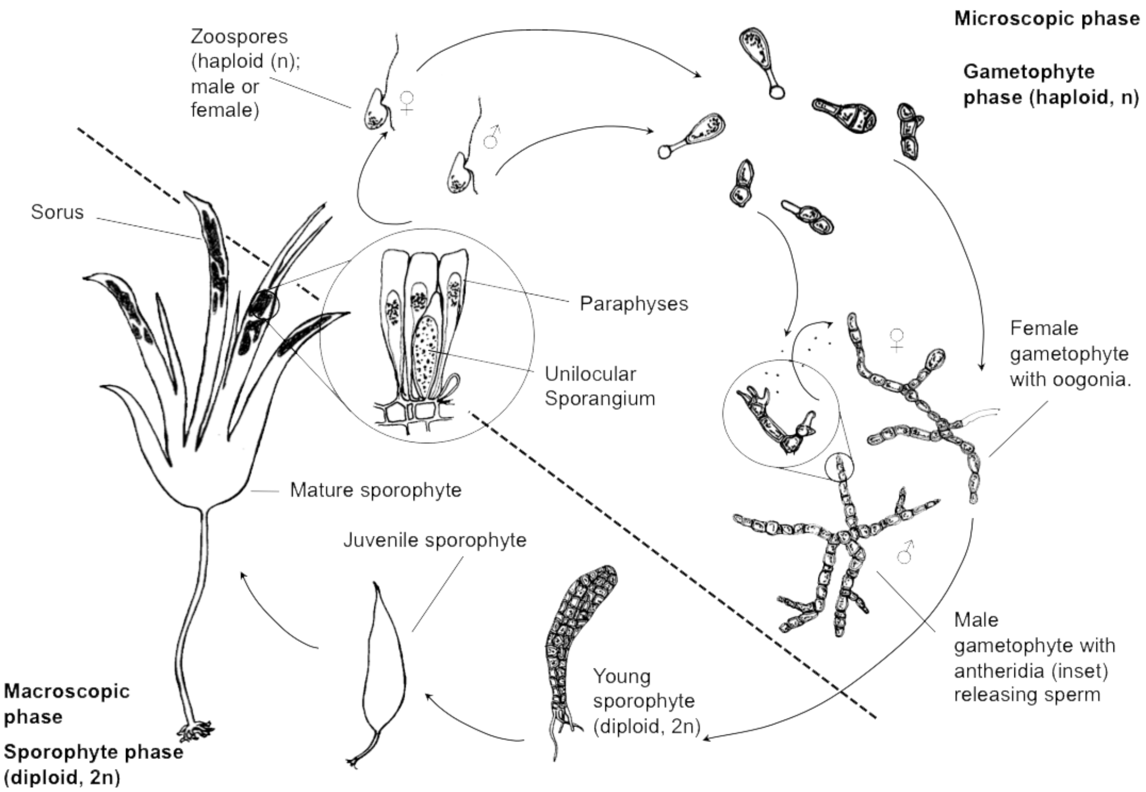

Figure 2: *Life cycle of* Laminaria digitata *(Source: Edwards & Watson, 2011).*

2.2.2 Basis set up of seaweed farm

The model is based on the cultivation system commonly practiced for *Laminaria digitata*. The production process of *Laminaria* is split up in the cultivation of plant material (culture strings with juvenile sporophytes) in a hatchery and the on-sea production of seaweed biomass (Figure 3).

In the hatchery plant material for the on sea installations is cultured. Ripe material is collected from the seaside and taken to the hatchery. Subsequently, reproductive material is selected and stored in seawater until ripe zoospores are released. The zoospores grow out to male and female gametophytes producing eggs and spermatozoids. After fertilisation a sporophyte develops. The sporophytes are sprayed on culture strings that are wrapped around a collector. The collectors are kept in a tank for 4-5 weeks for further growth of the sporophytes after which the culture string is deployed at the sea installations (longlines).

Depending on the seaweed species juvenile sporophytes can also be produced by *direct seeding* of zoospores on the culture strings instead of seeding juvenile sporophytes via gametophytes. In the model both cultivation systems can be chosen.

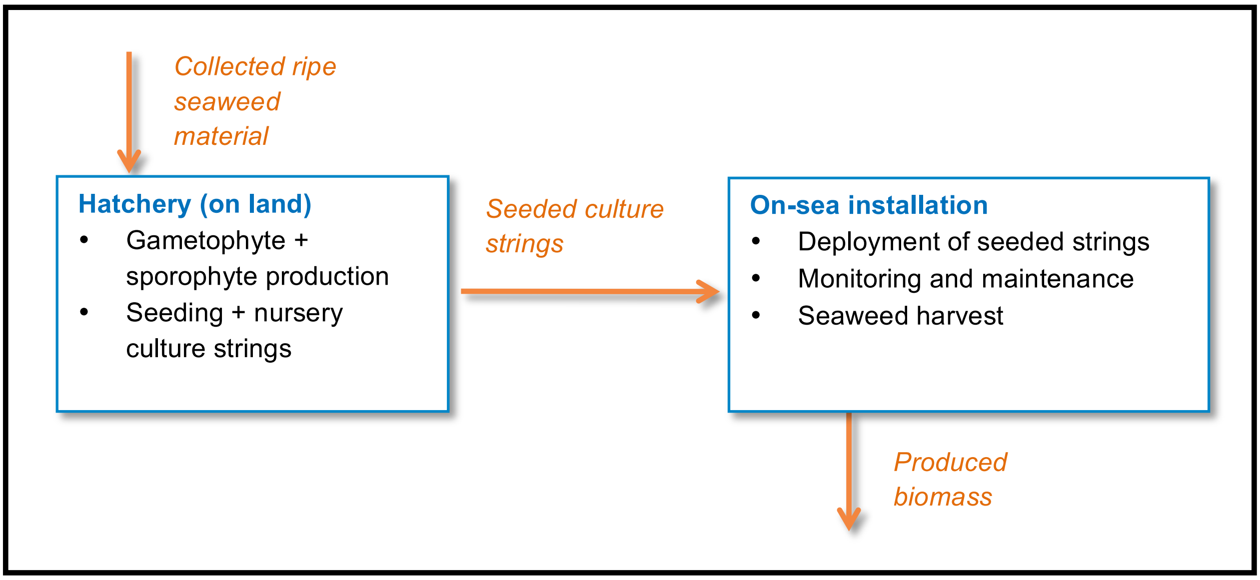

Figure 3: *Global schedule of macro algae production as used in the model.*

2.2.3 Hatchery

This paragraph describes the calculation of the costs for the hatchery. It must be emphasized that the result must be seen as an average estimation of the costs. For a specific situation a more detailed calculation is necessary taking into account the local conditions.

Periods

In a situation that young sporophytes are produced via gametophytes, the model distinguishes the period of juvenile sporophyte production via gametophytes in a growth cabinet and the nursery of seeded culture strings in an insulated cold room container unit. In a situation of direct seeding of zoospores the period of gametophyte production is skipped.

The gametophyte/sporophyte production is done in 6 litre flasks that are placed in a growth cabinet (see Figure 4). Lighting is by fluorescent tubes and the flasks are kept at a temperature of 10 °C. After sporophytes are developed (3-5 months), stimulated by changing the light regime in the growth cabinet, they are sprayed on a culture string that is wound around collectors (see Figure 5). The collectors are placed in tanks with prepared seawater and nutrients where the small sporophytes can grow out (4-6 weeks).

In an alternative direct seeding approach a mixture of harvested zoospores is sprayed directly on the culture string for deployment without the collector grow out phase.

Figure 4: *Growth cabinet as used at the Queens University of Belfast.*

Figure 5: *Wrapped collector (left) and collectors suspended in tanks (right) (Source: Edwards & Watson, 2011).*

Normally, deployment of brown kelps occurs in October-December, allowing two batches of seeded strings to be grown out per year in the hatchery for an early and a late deployment at sea (see Figure 6).

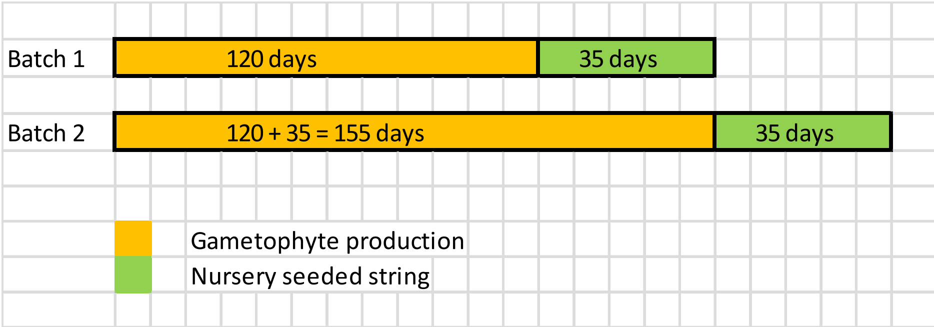

Figure 6: *Time schedule in hatchery for gametophyte/sporophyte production and nursery of seeded strings.*

In the sheet “Input_background” different parameters (i.e. lighting, refreshment frequency, duration) are given for the gametophyte/sporophyte production as well as the nursery of seeded strings.

Physical construction hatchery

In Figure 7 the physical set up of the hatchery is given. The hatchery consists of a seawater treatment unit, a growth cabinet for the production of gametophytes/sporophytes, a cold room for the nursery of seeded strings in tanks, a working room/laboratory and a wastewater treatment.

After pumping seawater in a reservoir, the water is pumped through 250, 10 and 1 µm filters and a UV-filter before it is used for refreshment of the water in the tanks for the nursery of seeded strings in the cold room. For the gametophyte/sporophyte production an additional treatment is done by autoclaving. The wastewater is treated in a wastewater treatment unit.

The production of gametophytes/sporophytes is done in a growth cabinet to regulate the light regime and to keep the temperature at 10 °C. The nursery of seeded strings is done in tanks that are placed in a cold room with lighting equipment and an air supply facility (blower with air distribution system to the tanks). The working room is used for the lab equipment (microscopes, precision scales, glassware), the growth cabinet and the autoclave.

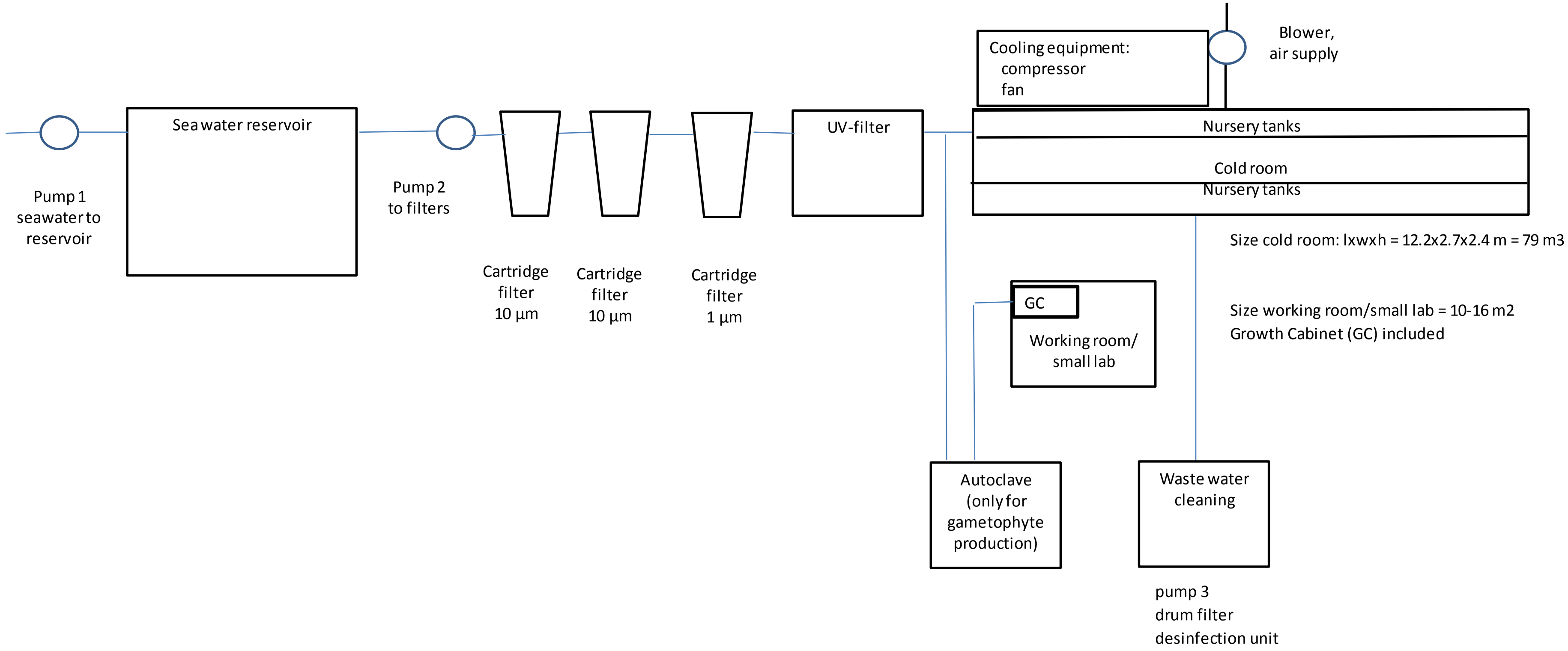

Figure 7. *Setup of the hatchery in the model.*

Cost calculation

Capital goods

In the sheet "Input_background" the investments costs for the capital goods are given. In Table 2 the default values are summarized. The main costs are the investments for the nursery of seeded strings (35%), the seawater treatment (25%) and the lab equipment (25%). This applies for a situation with gametophyte production. In a situation of direct seeding total costs for capital goods are decreased with about 10%.

Total yearly costs for capital goods are calculated as the sum of the depreciation costs (based on the investment costs and life span) and costs for interest, insurance and maintenance. For interest and insurance default values of 5.5% and 0.5%, respectively. If desired, these values van be adjusted in the sheet "Input_main".

Table 2. *Estimated investment costs (€) for a seaweed hatchery.*

	Hatchery system	
	Gametophytes	Direct seeding
Seawater treatment (pumps, filters, UV-unit, reservoir, pipework)	18,450	18,450
Gametophyte/sporophyte production (growth cabinet, culture flasks)	8,195	
Nursery seeded strings (cold room, lighting, tankage, air blow system, pipework)	28,130	28,130
Wastewater treatment (pump, drum filter, desinfection unit)	2,600	2,600
Lab equipment (e.g. autoclave, microscopes, precision scales)	19,600	19,600
Working room/lab	5,000	5,000
Total investment costs	*81,975*	*73,780*
Total yearly costs for capital goods	*9,360*	*8,525*

Consumables

The costs of consumables refer to nutrients, culture string and fresh water for cleaning. In the sheet "Input_background" required amounts and prices are given.

Electricity

Electricity demand is estimated by multiplying the electric power of the device with the time period in operation. Highest electricity demand is for cooling, lighting and air blowing (Table 3). In a situation of direct seeding of zoospores total electricity demand is decreased by about 25%. For the electricity price default values fort the participating countries are given in the sheet "Regional_data".

Table 3. *Estimated electricity demand (kWh/year) for the seaweed hatchery.*

	Hatchery system	
	Gametophytes	Direct seeding
Cooling (cold room, growth cabinet)	9,695	6,720
Lighting cold room[1]	1,210	1,210
Air blowing	3,520	3,360
Seawater treatment	410	410
Working room	305	305
Wastewater treatment	55	55
Total	*15,195*	*12,060*

1 lighting growth cabinet is included in the power for the growth cabinet

Labour

Labour demand is calculated by summing the estimated labour demand of the different activities during the hatchery period. Estimates are based on expert knowledge of the projects participants. Table 4 summarizes the estimated labour demand. In a situation of direct seeding of zoospores the labour demand is decreased by about 50%.

For labour price in the sheet "Region_data" default values are given for the participating countries. A distinction is made between low and high cost labour (default values: 80 and 20% of total labour demand is assigned as low and high cost labour, respectively). The low cost labour is based on minimum gross wages that is multiplied with a factor 1.35. This factor refers to social security charges and insurance. The high cost labour price is set a factor 2.2 higher than the low cost labour price.

Table 4. *Estimated labour demand (person days) for the seaweed hatchery.*

	Hatchery system	
	Gametophytes	Direct seeding
Collecting and preparing ripe material	4	3
Production gametophytes/sporophytes	36	
Nursery seeded strings	35	35
Total	*75*	*38*

Licenses

For costs for licenses a default value is given of €150 per year. If desired, this value can be adjusted in the sheet "Input_background".

Scale hatchery

The size and the costs of the hatchery in the model are based on the production of 22,000 m of culture strings. For a smaller farm, also a smaller hatchery is needed. However, in that situation the required size for the hatchery can become too small for a realistic operation. Therefore, in the model we have chosen for the following two options:

- The costs for the production of 1 metre culture string are calculated based on the hatchery size for production of 22,000 m culture string. This parameter (€/m culture string) is used as input for the seaweed farm. By doing so, the size of the on sea installation is uncoupled from the size of the hatchery.
- The model user can set the costs per meter culture string in the sheet "Input_main". This option is relevant for situations where a seaweed farmer is buying seeded culture strings instead of growing it by himself.

2.2.4 At sea growth installations

Installations
As mentioned before the model is restricted to the growing of macroalgae on longlines. Two subsystems are distinguished: a linear longline and longline with V-droppers.

Figure 8 shows the construction of a 100 m linear longline at sea. The culture string with the juvenile sporophytes is wound around the header rope (Figure 9) that is attached to anchor blocks at each side and is kept in place with buoys.

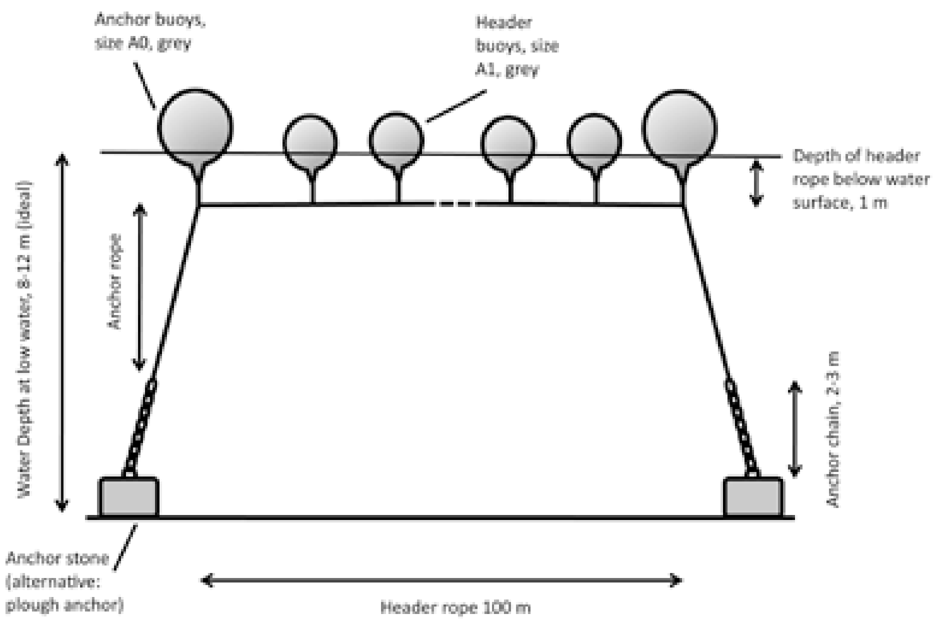

Figure 8. Construction of 1,100 m longline for seaweed cultivation (Source: Edwards & Watson, 2011).

Figure 9. Deployment of culture string along header rope of a linear longline (Source: Edwards & Watson, 2011).

Figure 10 shows the construction of a longline with V-droppers. The dropper rope is attached to the header rope of the longline in a V shape. The total length, depth and width of one "V" is 5.4 m (= 2*2.7m), 2.5 m and 2 m, respectively. This equals to a total length of V-droppers per 100 m longline of 270 m. The V's are kept in place by cement blocks.

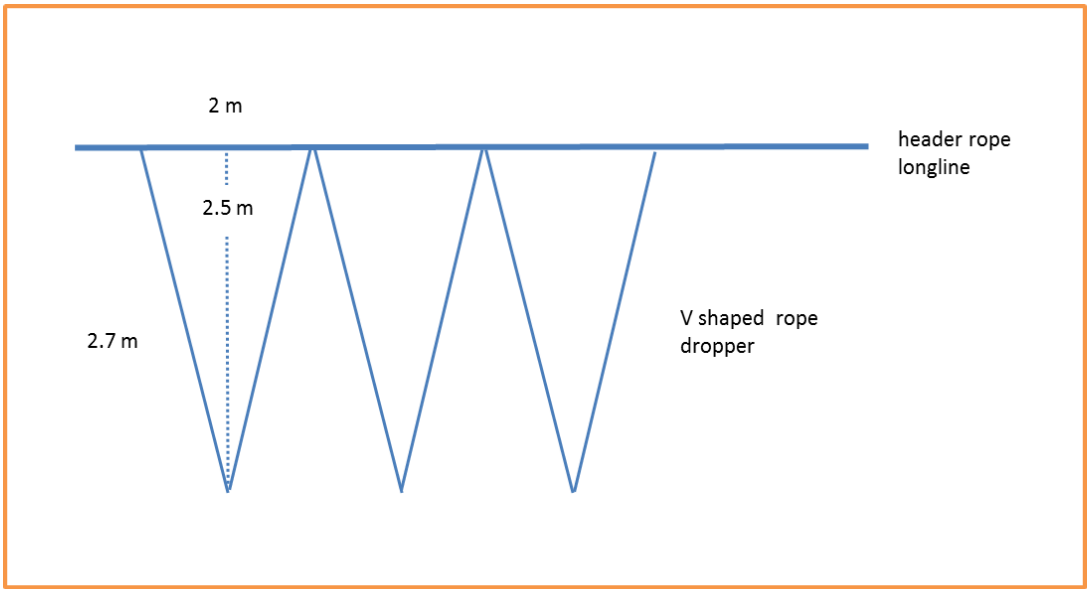

Figure 10. *Construction of a longline with V-droppers.*

In the sheet "Input_main" the user has to set the configuration parameters: number of longlines, distance between longlines and length of culture string/ m long line. From these parameters the needed length of culture string and the required sea area is calculated. *Please note that the length of the longline and the length of dropper rope/ m longline (in a situation with V droppers) at a value of 100 and 2.7 m, respectively, and cannot be changed.*

Costs calculation

Capital goods
In the sheet "Input_background" the investments costs for the capital goods are given for one 100 m linear longline. In Table 5 the default values are summarized (situation without and with V-droppers). The main costs are the anchor blocks. The given costs include the deployment at sea (so including costs for labour and boat).

Independent of the size of the sea site (number of longlines) it is assumed that four navigation buoys are needed to mark the corners of the site. If desired, the number of navigation buoys can be adjusted in the sheet "Input_background".

Table 5. Estimated investment costs (€) for one 100 m longline and one 100 m longline + V-droppers.

	longline	Longline + V-droppers
Header rope	350	350
Anchor rope and chain	300	300
Anchor blocks	1,550[1]	1,550[1]
Buoys	400	400
Trawl floats, shackles and tying rope	165	165
Dropper rope		15
Tying string + cement droppers		25
Total	*2,765*	*2,805*
Navigation buoys, 4	*11,840*[1]	*11,840*[1]

1 Including deployment at sea

For most calculations the farm will contain more than 1 longline. The scaling up will decrease the costs per longline. In order to account for this scaling effect we used the same method as used in the micro algae model (Spruijt et al., 2015). The used procedure originates from the chemical industry as published by Sinnot, Coulson & Richardson (2005):

$C2 = C1 * (S2/S1)^n$

In which:
C2 = capital costs at capacity 2
C1 = capital costs at capacity 1
S1 = capacity 1
S2 = capacity 2
n = scaling parameter

Figure 11 shows the costs when the above formula is used. When no scaling effect is applied the costs increase proportional with the number of longlines. Application of the scaling formulae shows that the value of the scaling parameter has a strong effect on total costs especially on larger scale (high number of longlines).

Unfortunately, data from commercial seaweed farms are only available on a very limited scale. We did compare the model results (run with different values of the scaling parameter) with data from a commercial Irish farm with 50 linear longlines. Based on the results it could be derived that a scaling parameter of 0.8-0.9 agrees with the data from the commercial farm. Currently, the scaling factor is set at a value of 0.8. However, we must emphasize that for a better underpinning of the scaling factor more data are needed from commercial farms differing in size.

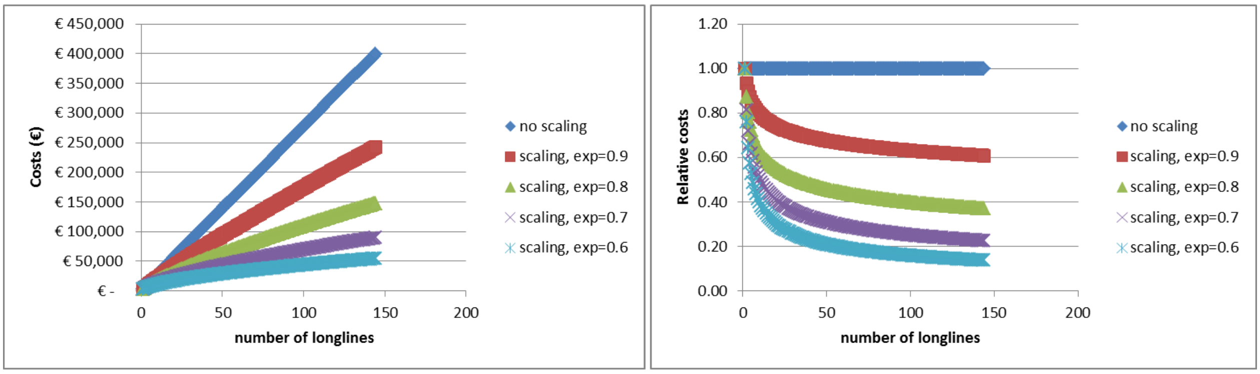

Figure 11: *Total costs capital goods (left: total costs, right: relative to situation with no scaling effect) in relation to the number of longlines as affected by the scaling parameter.*

Labour

Labour demand is calculated as the sum of the estimated labour demand of the different activities during the growth period at sea. Estimates are mainly based on data from the French Institute CEVA for a situation of 4 longlines. For situations with >4 longlines the labour demand is calculated by using the same scaling formulae as for the capital goods (see above) with the scaling parameter set at a value of 0.8.

Table 6 summarizes the estimated labour demand for a farm of 100 longlines for a system with linear longlines as well as longlines + V-droppers. The labour demand for a system with V-droppers is twice as high as the labour demand for a linear longline system. This is due to higher labour demand for deployment of culture strings and the harvest.

The monitoring is based on a growing period of 20 weeks and it is assumed that frequency of the monitoring is done 2-weekly. These values can be adjusted in the sheet "Input_main".

For labour price default values are given. As for the labour demand for the hatchery, a distinction is made between low and high cost labour (default values of 80 and 20% respectively).

Table 6: *Estimated labour demand (person days) for a farm with 100 longlines).*

	Growing system	
	Linear longline	Longline + V-droppers
Deploying seeded culture strings	19	56
Monitoring and maintenance	53	53
Harvest	47	139
Total, person days	*119*	*248*
Total, €	*13,600*	*28,170*

Boat costs

In the model it is assumed that a boat is hired (including a skipper). For a situation of 4 longlines the number of boat days is estimated and multiplied with the lease price (default value set at €800/day; value can be adjusted in sheet "Input_main") to get the total costs. For a situation with >4 longlines the boat lease costs are calculated by using the same scaling formulae as for the capital goods and labour demand with the scaling parameter set at a value of 0.8.

Table 7 gives the costs for boat lease for a situation with a linear longline as well as a longline + V-droppers. The costs in a situation with V-droppers are 2.2 times higher than in a situation with linear longlines due to the higher demand for the deployment of the culture string and the harvest.

Table 7: *Estimated costs for boat lease (€) for a farm with 100 longlines.*

	Growing system	
	Linear longline	Longline + V-droppers
Deploying seeded culture strings	2,130	8,530
Monitoring and maintenance	14,215	14,215
Harvest	17,060	51,180
Total, €	*33,405*	*73,925*

Transport to processing site

Once, the seaweed biomass is harvested and shipped to the harbour it has to be transported to the processing site. The costs consist of loading the harvested biomass on a van and transport to the processing site. For loading a default price of €5/ton is taken. The transport costs are based on a default price (€0.20/ton.km) and the distance from the harbour to the processing site (to be set in the model in the sheet “Input_main”).

Diving

Divers are needed to inspect, maintain and repair the sea installations. For the earlier mentioned commercial farm of 50 longlines the diving demand was estimated at three days for a 4 person team resulting in total costs of €4,500. This corresponds to a value of €90/longline used in the model, although it can be adjusted in the sheet “Input-main”.

License

A license is normally required for the use of the sea site for seaweed cultivation. The costs for the license are set at €50/ha and can be adjusted in the sheet “Input_main”.

2.2.5 Combined use

The model offers the opportunity to calculate the costs for capital goods in situations of combined use of the hatchery as well as the on-sea installations. Combined use is possible with another seaweed species or with shellfish. In the sheet “Input_main” the user can choose for combined use and, in that case, the percentage of the costs for capital goods that is allocated to the seaweed farm must be set (default: 50%).

2.2.6 Yields

The financial yield is depending on the physical yield and the price of the harvested product. Both parameters must be set in the model (sheet “Input_main”). As mentioned earlier, in contrary to the microalgae model, the macroalgae model does not calculate the yield level; it must be assessed by the user.

In a situation with longlines + V-droppers the yield per meter V-dropper line must be set (sheet “Input_main”). The default value is the same as for the situation with linear longlines resulting in a 2.7 times higher yield level per area as the total length of the deployed culture string is 2.7 times higher (see also Figure 10).

2.3 Description economics

The results of the economic calculations are shown in the sheet "Economics", based on the input parameters. In this section the calculated economic parameters are described.

Return
The total return (TR) is the product of the annual amount (YA) of harvested seaweed biomass and the selling price (SP):

TR = YA * SP

Costs
The total costs (TC) are the variable costs (VC) and capital good costs (CC):

TC = VC + CC

Variable costs (VC) are the yearly costs for nutrients, fresh water, electricity and labour. In the input sheets the assumed prices are set. These prices can be changed, when working with the model.

The purchase prices for capital goods are listed in the worksheet "Input_background". Capital goods costs (CC) are annual costs for depreciation, maintenance, interest and insurance.

Depreciation depends on the estimated lifetime for each item and the resale value (default 10%). The percentage maintenance cost is also estimated per item. The interest for capital goods is 5.5% which is 0.55*5.5% =3% per year at a resale value of 10%. Insurance costs are assumed to be 0.5%.

Results
The total result (RES) is the total return (TR) minus the total costs (TC):

RES = TR – TC

Cost price
The cost price (CP) is total costs (TC) divided by the amount of harvested seaweed biomass (YA):

CP = TC / YA

Return On Investment
The total investments for capital goods (IC) is the total of the purchase prices for the capital goods.

Return On Investment (ROI) is the total return (TR) minus variable costs (VC), minus maintenance and interest costs for capital goods (CC) divided by the total investment capital goods (IC), (depreciation and interest costs for capital goods are excluded from this calculation).

ROI = (TR – VC - CC – LC) / IC

Pay-back time
The pay-back time (PB) in years is the total investment capital goods (IC) divided by the total return (TR) minus variable costs (VC), minus maintenance and interest costs for capital goods (CC) and minus land costs (LC), (depreciation and interest costs for capital goods are excluded from this calculation).

PB = IC / (TR – VC – CC1 – LC)

3 Model calculations

3.1 Presentation of the results

The results of the calculations are summarized in the sheet “Economics_sum”. In this sheet the costs for producing the plant material in the hatchery and the costs for the total farm are given. The results are presented in tables as well as bar diagrams showing the make-up of the cost price. Figure 12 shows the results of a model calculation for a seaweed farm with 100 linear longlines and a total production of 100 tons of fresh seaweed biomass. In this situation the cost price is €1.10/kg FW consisting of costs for plant material (10%), capital goods (32%), boat lease (33%), labour (14%) and other costs (11%). In the right hand figure the cost price of the plant material is given. Total cost price is €1.05/m culture string. The major costs consist of costs for capital goods (40%), consumables (16%), labour (37%) and electricity (6%).

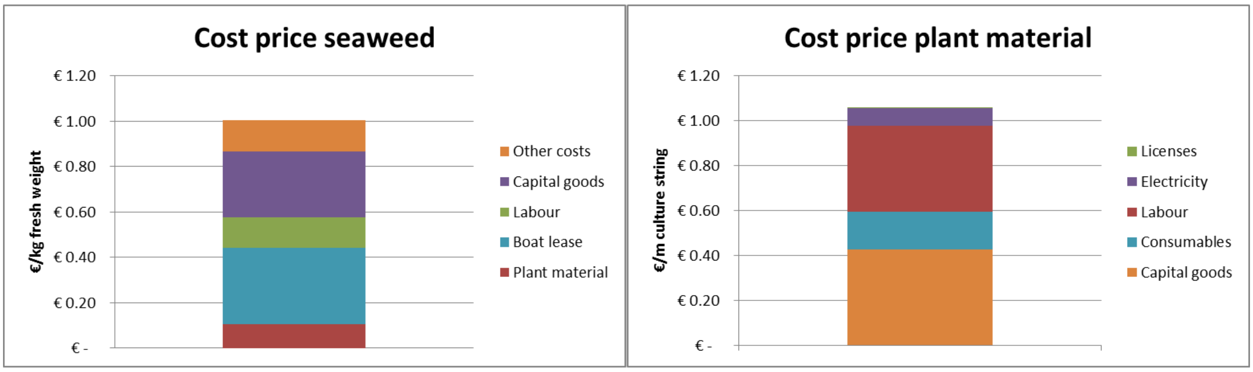

Figure 12. *The make-up of the cost price (€/kg FW) for a seaweed farm with 100 linear longlines (left) and the make-up of the cost price of plant material (right, situation with gametophyte production).*

The model also summarizes the most important economic parameters of the seaweed farm. In Table 8 an example is given for the farm with 100 linear longlines. The calculations are shown for three alternative selling prices.

Table 8. *Economic parameters for a seaweed farm of 100 linear longlines.*

	Selling price (€/ kg FW)		
	1.00	1.20	1.40
Total return, €	100,000	120,000	140,000
Total costs, €	100,500	100,500	100,500
Total results, €	-500	19,500	39,500
Return/100 € costs	100	119	139
Selling price, €/kg FW	1.00	1.20	1.40
Cost price, €/kg FW	1.01	1.01	1.01
Total investments[1], €	122,996	122,996	122,996
Return on investments, %	<0	16	32
Pay-back time, year	<0	6	3

1 Investments for on sea installations

3.2 Varying input parameters

In this section the results of different scenarios are presented. The base scenario is a seaweed farm with 100 linear longlines. The cost price of the plant material is calculated by the model. Total wet biomass production is 100 tons. The longlines as well as the hatchery is not used for other activities (no combined use). Subsequently, the following input parameters are changed to assess their sensitivity against the base scenario:

- Size of the farm
- Cultivation system at sea
- Cultivation system hatchery
- Combined use of facilities

Size of the farm

Figure 13 shows the calculated cost price as affected by the size of the farm. The effects of farm size on the cost price are strongest at lower scale levels. For a farm of 10 and 100 longlines cost price is €1.72/kg FW and €1.01/kg FW, respectively. A further increase of the farm size has a smaller effect on the cost price.

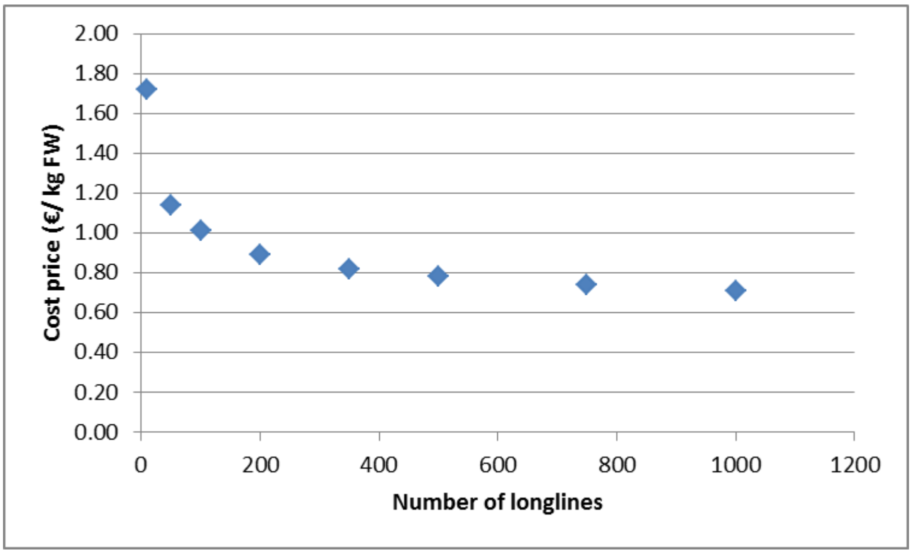

Figure 13. *Calculated cost price as affected by the size of the farm (number of longlines).*

Cultivation system

The model offers the opportunity to choose for different cultivation systems. For the on sea installations a system with linear longlines or a system with longlines and V-droppers can be chosen. For the hatchery a distinction is made between growing plant material via gametophytes or via direct seeding of zoospores. Table 9 gives the calculated cost price for the different systems.

The effect of the system for the on sea installation is considerable. For the system with longlines + V-droppers cost price is about €0.35/kg FW lower than for a system with linear longlines. This is mainly due to the higher yield per area, as the costs are higher. The effect of cultivation system in the hatchery has only a minor effect on the cost price.

***Table 9.** Cost price seaweed as affected by cultivation system.*

On sea installation	Hatchery	Cost price (€/kg wet)
Linear longlines	Gametophytes	1.01
	Zoospores	0.98
Longlines +V-droppers	Gametophytes	0.67
	Zoospores	0.65

Combined use of facilities

The hatchery as well as the on sea facilities can also be combined with other activities like shellfish production. This means that costs for capital goods can be shared with the seaweed as well as the other activity decreasing the total costs for the seaweed farm. Table 10 shows the effect for combined use for a situation where 50% of the cost for capital goods is allocated to the seaweed farm. The cost price decreases with about €0.15/kg FW when the facilities for the on sea installations as well as the hatchery are shared. The effect of sharing the on sea installation is far stronger than sharing the hatchery due to the fact that cost for capital goods of the on sea installations contribute more to total cost price that the costs of the plant material.

In a situation with combined use also the cost price for the other activity will decrease (Edwards & Watson, 2011), but this is outside the scope of the model. It has to be emphasized that we used a simple calculation method that does not account for a decreased life span or increased costs for maintenance when using the facilities more intensively. Therefore, the model outcome must be seen as the maximum effect to be expected.

***Table 10.** Cost price seaweed as affected by combined use of hatchery and on sea facilities.*

Combined use on sea installation	Combined use hatchery	Cost price (€/kg wet)
No	No	1.01
Yes	No	0.86
No	Yes	0.98
Yes	Yes	0.84

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INTERREG IVB

EnAlgae is a four-year Strategic Initiative of the INTERREG IVB North West Europe programme. It brings together 19 partners and 14 observers across 7 EU Member States with the aim of developing sustainable technologies for algal biomass production.

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