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Assessment of Financial Feasibility of Farming Blue Mussel in the Great Belt by the 'Smart Farm System'

Thong Tien Nguyen

Mads Anker van Deurs

Lars Ravn-Jonsen

Eva Roth

Department of Environmental and Business Economics (IME)

University of Southern Denmark

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UNIVERSITY OF SOUTHERN DENMARK

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By

Thong Tien Nguyen (SDU)

Mads Anker van Deurs (NordShell)

Lars Ravn-Jonsen (SDU)

Eva Roth (SDU)

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Thong Tien Nguyen
Department of Environmental and Business Economics
University of Southern Denmark
Niels Bohrs Vej 9-10
DK-6700 Esbjerg

Mads Anker van Deurs
NordShell
Bergmannsvej 26
5700 Svendborg

Lars Ravn-Jonsen
Department of Environmental and Business Economics
University of Southern Denmark
Niels Bohrs Vej 9-10
DK-6700 Esbjerg
Tel.: +45 6550 4208
Fax: +45 6550 1091
E-mail: lrj@sam.sdu.dk

Eva Roth
Department of Environmental and Business Economics
University of Southern Denmark
Niels Bohrs Vej 9-10
DK-6700 Esbjerg
Tel.: +45 6550 4186
Fax: +45 6550 1091
E-mail: er@sam.sdu.dk

Preface

MarBioShell is a research project aimed at evaluating the potential for production of line-mussels (*Mytilus edulis*) in the Great Belt (Denmark) to compensate for the present decrease in landings from Danish fjords and coastal waters. The project is supported by the Danish Agency for Science, Technology and Innovation in the period 1 January 2008 to 31 December 2012.

In the laboratory, bioreactor technology is applied to provide controlled mass production of planktonic algae to be subsequently used in controlled growth experiments and bioenergetic and biochemical studies of food intake and assimilation in mussels. In the field, comparative studies of actual growth and production of mussels of different size in selected areas in and outside the Great Belt region are performed with special emphasis on the importance of salinity, current speed, and amount of phytoplankton (chl *a*) in the ambient water.

Market analyses are carried out to estimate whether product differentiation and consumer preferences contribute to the economic sustainability of the suggested new line-mussel production facilities in the Great Belt. Business network and branding, as well as local innovation systems are surveyed and used for future investment decisions.

A research and demonstration line-mussel farm is established in the southern part of Kerteminde Bay, close to the Great Belt. The research and demonstration facility is a unique opportunity for all work packages within the MarBioShell project to work together in solving the main common task, namely to clarify the potential in the broadest sense of cultivating mussels in the Great Belt.

Besides coordinating the research activities among the participants, the MarBioShell network intends to support a broader communication to and between national and international companies, research teams and public authorities.

This report provides aquaculture investors and public authorities with the information of financial feasibility of farming mini-mussels in the Great Belt. The profitable assessment in this report utilizes the results from various working packages within the MarBioShell project and other information and assumptions that are the most reliable. The report provides useful information for investors and public authorities in deciding on investment opportunities and subsequent public policy.

Contents

Executive Summary

- This report aims to investigate financial feasibility of farming blue mussels (*Mytilus edulis)* in the Great Belt, Denmark, at a commercial scale. We suggest producing a new mussel product, Mini Mussels, with a shell length of around 35mm after 7-8 months of growth. The blue mussels are extractive and filter feeding species. Therefore, if mussel cultivation is integrated with fish farming in an integrated multi trophic-system, the multiple benefits for both mussel and fish farmers are expected. In the integrated farm system, mussels can clear fish feed and faece particles out of suspension with a high efficiency and mussels have a better growth, compared to the mussel from wild stock and other traditional farm systems.
- The Great Belt (Storebælt) is the largest and the most important of the three straits of Denmark that connect the Kattegat to the Baltic Sea. The belt has high potential for farming blue mussels, as the Great Belt receives the runoff from the Baltic's agriculture, which provides large quantities of nutrients. If only 2% of the current passing through the Great Belt is used for mussel farming, it is possible to produce 200,000 tons of mussels per year.
- We suggest using a low labour intensive cost farming system, namely 'Smart Farm system' (www.smartfarm.no). The farm size for each individual farming company is 800 smart units, in which the mesh has both vertical and horizontal dimensions which mussels can attach to. The farm can produce about 20,000 tons raw materials mussels per cycle (year). The farm productivity is expected at 4.15 kg mussels per m of rope. The farming starts in May and mussels may be harvested in October, November, and December. The mini mussels have smaller size than traditional marketed mussels, but at least as much meat content as the traditional mussels from wild stock or other farming methods with a production cycle of 15-20 months.
- The investment for the farming system costs about 18 €M and the system can be used for at least ten years with annual operation costs of around 0.9 €M. The farming works are carried out by only three employees with full time jobs.
- We estimate that about 80% of the mini mussel production is supplied for producing feed for fish and poultry and 20% is used for human consumption. The selling price of raw material mussels for processing fish and poultry meal is 0.1€/kg and for human consumption

0.83€/kg. In addition, the mussel farmers are expected to get paid an amount of 0.2€ for each kg mussels from fish farmers or other polluters for the contribution of environmental benefits. In sum, the expected price of selling mussels is about 0.446€/kg.

- We estimate that net profit (after income tax) of the project is 3.2€M per year. With a discount rate of 6% per year, the project has a Net Present Value (NPV) of 19.8€M and the Internal Rate of Return (IRR) of 25%. At the Break Even-Point (BEP) (i.e. NPV equal zero), the selling price is 0.223 €/kg while other factors are constant or the productivity is 2.08 kg/m while other factors are constant. After four years, the investors can get back the investment fully.
- The prices of mussels and productivity are the most uncertain factors driving the profitability of the projects. Examining simultaneously price, productivity, and other input factors in a sensitivity analysis we found that the project has positive NPV (at 6% discount rate) with a probability of 97.8%, and the project could have NPV of 18 €M or higher with a probability of above 50%.
- If the mussel farmers will not get paid from fish farmers and other polluters for the contribution of environmental benefits, the project is still profitable, with NPV of 2.03 €M and IRR of 8.2%. However, the probability of the success (positive NPV) is only 52.9%.
- We suggest that the farm size for a single farming company should be above 102 smart units to get the profit. The bigger size can efficiently utilize the economy of scale.

1. Introduction

Denmark was one of the largest suppliers of wild stock blue mussels in Europe and the world (Thong 2012). However, catches have been more than halved in recent years because of overfishing. Overfishing, minimum mussel size limit, oxygen depletion and environmental problems are plaguing the trade. Mussel dredging is harmful to the bottom and the marine environment. The population of mussels in Limfjorden has fallen since 1993 by an average of 34,000 tons per year, and in August 2006 after extensive oxygen depletion, the stock went down to 150,000 tons (Riisgård et al. 2012a).

On the other hand, cultivation of blue mussels in Denmark is far from fully developed. Mussels are farmed in Europe by two types of method; that are bottom and suspended culture (Buck *et al* 2005).The cultivation of blue mussels based on traditional methods has been developed in Limfjorden and Sydfyns Øhav but did not succeed. The traditional cultivation of line-mussels has several limitations:

- Labour intensive and unprofitable cultivation systems due to high wages in Denmark. The small free-swimming mussel larvae that settle on the ropes must be thinned, graded and returned back into the sea in net-materials with a certain low density which requires much manual work.
- Slow and risky production, because it takes two seasons (18 months, see Dolmer & Frandsen 2002) for mussels to reach the minimum shell length that is 4.5 cm. During winters with storms and ice the mussel-farm systems may be destroyed, and due to starvation (no phytoplankton) the mussels also lose weight over winter. Most line-mussel farmers in Limfjorden have so far failed and not succeeded in establishing a profitable farm. The same was true for Sydfyns line mussels, which after 5-6 years closed down in 2009. In 2008 there were about 12 line-mussel farmers in Limfjorden, but after two winters in 2009 and 2010, only two line-mussel farms were in operation in 2011.

The MarBioShell project (www.marbio.sdu.dk) has shown that the Great Belt region has generally good growing conditions for line-mussels (Riisgård et al. 2012a,b,c,d; Larsen et al. 2012). Here are strong currents and there are no oxygen depletion problems during the summer as in many of the shallow Danish fjords. On this background the MarBioShell project has identified a number of advantages by focusing on the cultivation of ‘mini-mussels’.

In this report we present the assessment of financial feasibility of farming mini-mussels in the Great Belt regions. The mini-mussels are cultivated in a ‘Smart Farm system’ for 7-8 months to reach the market size of 3.5cm. The size of mini-mussels is smaller than the traditional but has the same relative meat content as the traditional mussels. Moreover, the new farming system could be profitable because it avoids the limitations that the traditional cultivation of line-mussels faces. In this report we present the brief overview of the farming region of the Great Belt, mini-mussels as a new product, and assessment of the financial feasibility of the farming project.

2. Farming Blue Mussel in the Great Belt

2.1. Environmental Conditions

The Great Belt (Storebælt) is the largest and the most important of the three straits of Denmark that connect the Kattegat to the Baltic Sea. The Great Belt is 60 km (37 miles) long and 16–32 km (10–20 miles) wide. The Great Belt forms the transition between the tidal North Sea and the non-tidal Baltic Sea (see Figure 1). The water exchange between the Baltic Sea and the open sea is driven both by the river run-offs, by the meteorological conditions over the North Sea -Baltic Sea area (Kullenberg & Jacobsen 1981; Møller 1996) and the tide. The surface salinity in the South-East Kattegat is low, less than 20‰ , whereas the salinity beneath the halocline at about 15 m depth is high, about 30-34 ‰. Due to shifting winds, the water level difference between Kattegat and the Western Baltic Sea is highly variable causing an oscillating flow through the Straits.

In the Great Belt the salinity varies according to changing flow situations. Outflow of water from the Baltic Sea gives salinities down to less than 10‰, whereas inflow to the Baltic Sea gives salinities up to 27‰ in the upper layer of the Great Belt. Normally, the actual current speed through the Great Belt is about 50 cm s^{-1}. The annual mean chlorophyll-a concentration in the period 1998-2009 in the northern Great Belt was 3.8±3.0 mg chl a l^{-1} (Riisgård et al. 2012a).

Figure 1: The Great Belt (Source: gst.dk)

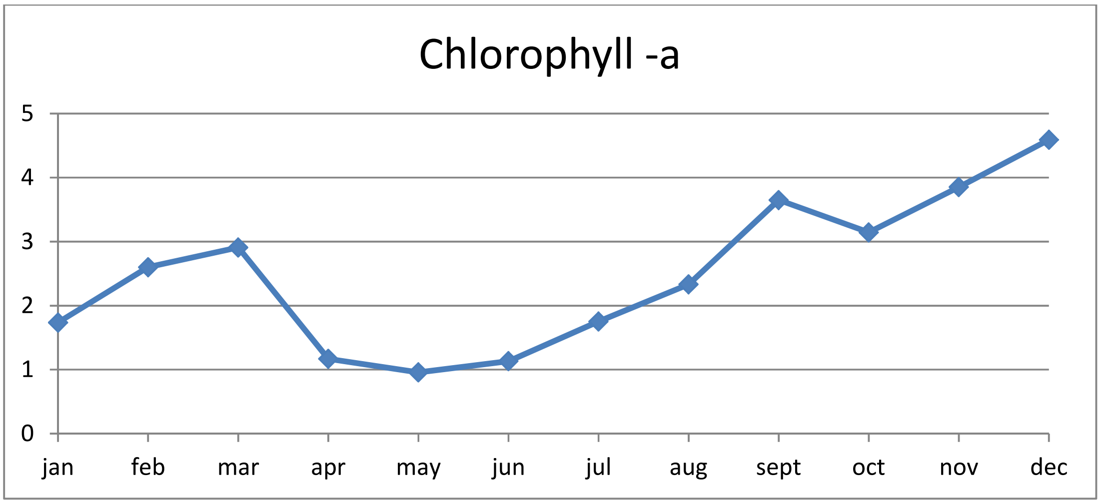

Figure 2: Chlorophyll-a concentration in the Southern Great Belt in 2011 (Source: DHI data)

The concentration of all inorganic nutrients peaks in January and February as a result of accumulated mineralization during late autumn-winter and land run-off, combined with a low isolation preventing phototrophic production and uptake of nutrients in algae (DHI 2011).

Nutrients and in particular dissolved inorganic nitrogen (DIN) decrease in March due to the spring bloom and DIN remains exhausted until November. In contrast, phosphate is still available at the end of April and the concentration is varying between 2 and 5 mg PO4-P m-3 from May through to August. From September through to December the concentration of phosphate increases gradually reaching peak winter values in January (Figure 2).

2.2. Blue Mussels Ecology

Blue mussels have a widely distributional pattern, mainly due to its abilities to withstand wide fluctuations in salinity, desiccation, temperature, and oxygen tension. Therefore, this species occupies a broad variety of microhabitats, expanding its zonational range from the high intertidal to subtidal regions and its salinity range from estuarine areas to fully oceanic seawaters. Highly tolerant to a wide range of environmental conditions, the blue mussel is euryhaline and occurs in marine as well as in brackish waters down to 4‰, although it does not thrive in salinities of less than 15‰ and its growth rate is reduced below 18‰. Blue mussels are also eurythermal, even standing freezing conditions for several months. The species is well acclimated for a 5-20 °C temperature range, with an upper sustained thermal tolerance limit of about 29 °C for adults. Its climatic regime varies from mild, subtropical locations to frequently frozen habitats. Blue mussels typically occur in intertidal habitats, although this distribution appears mostly controlled by biological factors (predation and food competition) rather than by its capacity to survive subtidally, as demonstrated by offshore mussel culture using suspended method (FAO 2004).

Phytoplankton is a natural feed that is selected by blue mussels prior to ingestion with selection further made between different phytoplankton species and other organic and inorganic particles. The growth rate of blue mussels depends on the nutrient composition of absorbed particulate organic phosphorous (*Chl a*), nitrogen and carbon (Handå 2012). They also feed on the other particles such as used fish meal and fish faece.

2.3. Great Belt's Sustainability for Mini-Mussel Farming

In the Great Belt there is a natural settlement of mussel spat in the early summer. After the settling of the larvae the mussels will grow fast during the summer and autumn due to the steady current leading new feed through the mussel farm at all times. When mussels are situated on the nets in the mussel farm they are protected from predators on the seabed like starfish, crabs and others. The mussels will filtrate continuously and grow at a high rate and can be harvested as mini mussels in the late autumn. If just 2% of the current passing through The Great Belt is used for mussel farming, it is possible to produce 200,000 tons of mussels (source DHI). A production as suggested in this document will only use about 2% of the nutrients passing the Great Belt and this deduction will benefit the local environment counteracting the yearly lack of oxygen at the seabed.

Due to the local environmental conditions of the Great Belt, we suggest to cultivating of mini-mussels as the size of 35mm is reached after only 7 months of growth. The cultivation of mini mussels in the Great Belt has some benefits:

- Mussel larvae that settle on the cultivation lines (ropes) in May-June grow rapidly and attain a shell length of about 30-40 mm in one season so that they can be harvested from October to December.
- Constant high water-flow in the Great Belt provides a uniform product with little variation in size, high meat content and a very low ratio of useless mussels. One mussel of 35 mm shell length grown in the Great Belt contains as much meat as a 45 mm mussel dredged in Limfjorden (dry weight of meat is 15% of wet weight with shell).
- There is no minimum size limit for cultured mussels, and therefore the growth period can be reduced to one season (May to December). Small mussels harvested in October-December will not be plagued by epifauna such as ascidians, tubeworms and barnacles on the shells.
- Growth in the Great Belt can take place in the whole water column (*i.e.* at least to a depth of 8 m) and therefore approximately 30-40 kg per m^2, equivalent to 3-4000 tons per year within a normal production area of 250 × 750 m. One percent of the water passing through the Great Belt can provide enough "food" for 10 mussel farms.
- The mussel-farm system can be packed together and placed on land during winter if necessary.

- Mini-mussels are more delicate and taste better than large mussels (like: lamb versus sheep, calf versus cow, sucking pig versus adult pig, small chicken versus big hen), and mini-mussels may enter into new, exciting and tasty types of dishes after exotic model where small mussels and clams are traditionally used in many dishes.
- Mini-mussels contain more unsaturated fatty acids than large mussels (Pleissner et al. 2012).
- Harvested juvenile mussels that have not grown up with the new minimum size (30 mm) for mini-mussels during the season may instead be used as for example chicken and fish feed, and the harvested mussels also help to remove nitrogen (N) and phosphorus (P) from the marine environment, cf. compensation culture (Lindahl et al. 2005, Lindahl 2011, Møhlenberg et al. 2008).

Because blue mussels are extractive and filter feeding species, we suggest to cultivating the blue mussels close to fish farms. The cultivation method is named as the integrated multi-trophic aquaculture that can contribute to a more ecologically balanced ecosystem approach in marine aquaculture (Handå 2012). In the farming areas of salmon in Norway, for example, Wang (2012) investigated that of the total feed input, 70% C, 62% N and 70% P were released into the environment. These considerable amount of feed used and released to the surrounding water area could potentially impact negatively on the fish growth. However, in the integrated farm system, mussels can clear fish feed and faece particles out of suspension with a high efficiency and mussels have a better growth (Handå 2012).

2.4. 'Smart Farm System' for Mini-Mussel Farming

Based on the information and data available, we suggest using the 'Smart Farm system' supplied from the Norwegian company (www.smartfarm.no). The farming technology is all based on SmartUnits with polyethylene pipes for carrying the biomass and moorings to absorb active forces and necessary flexibility (see Figure 3). The SmartUnit is a complete assembled unit consisting of:

- PE-pipe for buoyancy
- Head-rope with thimbles for easy mooring

- Bottom-weights
- Collector – Mesh-size and rope thickness according to specific needs.

A SmartUnit consists of 6.067 meters of horizontal and vertical collector rope, which forms the space for mussel growth.

Figure 3: 'Smart Farm System'

We chose the 'Smart Farm system' as this system has proved to be the most cost efficient system on the market due to low labour cost, high performance and reliable hardware. The farming system and equipment have an expected lifetime of 10 years. Under favourable conditions after

10 years' use, the system and infrastructure may be renovated for an additional 10 years' further use by new rope-loops on the smart-units, new moorings and navigational markings, and a new smart scooter, major refit on boats. It is therefore assumed that after 10 years the scrap value of the equipment is about 10% of initial investment.

A mussel farm, organized in a single company may need the following infrastructure; targeting a production of about 20,000 tons of blue mussels per year.

This size is equivalent to 800 smart-farm units, which consist of 4,853,600 meters of horizontal and vertical collector rope. A farming company can operate 800 Smart Farm units preferably divided into 6 plots.

The harvesting machine and the boat are the biggest investment and should be in use as much as possible in order to get the best return of the investment. A harvesting machine can harvest up to 30 tons per hour with (experience from Germany). In this calculation we assume 200 tons per day. The time for harvest will then be around three months. For the rest of the time the boat and machine will be used for husbandry, maintenance like tensioning the anchors, cleaning the nets and submerging the units before winter etc. The harvest capacity is then 20,000 tons per season. In the calculation we set one unit to 27 tons resulting in a total of 800 Smart Farm units (4.15 kg pr. meter x 6,000 meters per unit). The 800 units can be situated in farms on different locations in the Great Belt.

A farming cycle takes 7 months from May/June to November/December. This period is the best time around the year for mussel growth and accumulating meat content. After this period, mussels still grow in size but meat content will be reduced during the winter time.

The project assumes that owners can recover the working capital at an interest rate of 6%. The total working capital is calculated at 1 €millions (see below).

We summarize the assumptions in Table 1.

Table 1
Basic Assumptions

Farming method	Smart-farm system
Farming time (one cycle)	7 months (May to November)
Number of farming units	800 units
Length of ropes (vertical & horizontal)	4,853,600 m
Productivity (kg/m)	4.15 kg/m
Total production (kg/cycle)	20,142,440 kg
Lost ratio (during transportation)	25%
Size of mussels	35 mm
Meat content index of mussels	27%
Labour cost	35 €/hour
Running cost for large vessel	51 €/hour
Running cost for SmartScooter	51 €/hour
Running cost for small boat	26 €/hour
Maintenance cost (% of initial price)	0.1-1%
Profit tax (%)	20%
Interest rate	6%/year
Working capital	1 million Euro
Scrap value of equipments after 10 years	10% initial value

3. Markets for Mini-Mussels

Mussels have been the traditional seafood in many European countries for 1,000 years (Smaal 2002). Global annual mussels production reached about 1.7 million tons in 2008 (FAO 2009); about 94% was due to farmed production. Many European countries have a long tradition of consuming mussels including France, Italy, Spain, Belgium, and the Netherlands. There are two typical mussel species supplied for human consumption in the EU; they are blue mussels, *Mytilus edulis*, which is farmed and harvested along the Atlantic and North Sea coasts, and the Mediterranean mussel, *Mytilus galloprovincialis*, which is farmed in the Mediterranean, Adriatic, and Black Seas, and in the river basins (Rias) of Northwest Spain (Smaal 2002).

Blue mussels are supplied to the market in forms of fresh, chilled and frozen products. The fresh and chilled products are preferred and command a higher price. The frozen product is cooked mussel meat that may be mixed with other seafood such as octopus and shrimp or may be the pure cooked meat of mussels packed in 0.5 kg. Europe produces about 500,000 tons of fresh mussels annually, which accounts for about 50% of total global mussel production (FAO 2009), and 90% of the production due to farming (Thong 2012). Five major producers in Europe (Spain, Denmark, Italy, France, and the Netherlands) produce about 80% of Europe's total mussel volume.

Production within European waters is used mainly for consumption within the continent. To supplement demand, Europe has spent about €30M annually during the last decade to import mussels (Thong 2012). Mussels imported to the EU are mostly frozen and prepared products from New Zealand, Chile, and Turkey. Chilean frozen mussels are very competitively priced and have significantly influenced prices of both fresh and frozen European mussels. Based on available data of production and import-export volume, we estimate that Europeans consume about 704,000 tons of mussel per year (live weight), more than 90% of which is supplied by its own production. France, Italy, Belgium, and Spain are the major markets for mussels. The Netherlands and Denmark are traditional mussel producers, but domestic consumption in these countries remains very low. Belgium does not produce mussels, but is one of the major markets for the product. All mussels consumed in Belgium are imported fresh from the Netherlands (Thong 2012).

For mini mussels there are two possible markets: a) one is for human consumption, including fresh and chilled form, frozen mussel meat may be mixed with other seafood, and a precooked ready meal, b) another part may be used as input raw materials for processing feeds for chicken or fish. The fresh, chilled and frozen mussels are traditionally consumed in many European markets. However, these blue mussels normally have a size of above 45mm that may be supplied from cultivation or wild stock harvest. Mini mussel is a new product and we expect the mussels can be used partly as raw material for precooked ready meal (see Figure 4). For instance, the patented system Micvac (www.micvac.com) has been developed on the basis of mussels but is now used for various dishes. This is a fully automatic processing line for cooking and packing of ready to eat meals (convenience food).

Figure 4: Example of precooked ready meal made from mussels

Mussels can be processed to the meal for feeding fish or poultry. The feed made from mussels can replace the feed made from fish with some advantages. For example, mussel feed gives a stronger york colour of egg and stronger colour of Salmon trout, compared to fish meal (Odd Lindahl). In addition, mussels can be used as fertilizer and energy.

We assume that about 20% production of mini mussels from this project will be supplied for direct human consumption, whereas 80% is expected used to process feeds for fish and poultry. This is a very strong assumption as the market for mini mussels as well as the market for mussel meal feed has not yet been developed. In the future, the proportion of the production used for food production may be increased.

4. Costs

4.1. Investment cost

The investment costs have two components:

a) *Farming equipments:* including smart units, mooring for units, navigational markings, and Eider duck fence.

- Smart Farm units account for the major cost of farming equipments. The unit price of smart unit is 15,765€/unit. An 800 unit farm needs an initial investment for equipment is 12,612,800€.
- The moorings are used to fix the smart units in the farming positions; the unit price of the mooring is 3,878€/set. An 800 unit farm needs 800 mooring sets, which cost 3,120,400€.
- Eider duck fence is used to prevent Eider duck from eating pre-mature mussels. The Eider duck is quite prevalent in the Great Belt and they can eat most of the mussels before harvest. In this calculation we have assumed use of 8,000 meters of fence at a cost of 35 € per metre, which is the total investment of 280,000€.
- The farm needs 64 sets of navigational marking, and the unit price is 2,822/set; the investment is 180,608€.
- The transport and delivery cost is assumed to be 9,500€ pr. mobilization/delivery, we have here made room for splitting the delivery into 2 different periods, which cost totally 19,000€.
- The installing cost is calculated based on the number of working hours in the field assembling and installation of the moorings and the SmartUnits at the site. It is estimated a cost of 327.4 € for installation of a smart unit. The total installing cost is estimated at 261,920€.

After being set into the water, the ‘Smart Farm system’ will be laid in the field for many farming cycles. After a harvesting season, the system is simply sunk into the seabed to avoid the damage from ice during the winter.

b) *Infrastructure for works at sea***:** including two boats, smart scooters, other tools.

- A working boat is needed for farming activities including preparing settlement, removing starfish, harvesting, ect. The initial price of the working boat including harvest machine is estimated at 1,000,000€. The working boat and harvest machine can be used to harvest 20,000 tons mussels per cycle (one year).

- A small boat is used to navigate between land and the farm, and also used to support other farming activities. The initial cost of the small boat is estimated at 100,000€.
- Smart scooters are used to clean the farming system after harvest. The initial price of a smart scooter is estimated at 460,000€.
- Selection of other tools includes spares, brushes, dewater unit, and accessories. The total cost of these tools is estimated at 40,000€.
- The transport and delivery costs are estimated at 12,500€.

Table 2 presents more detail on the investment costs. We assume that the equipments and infrastructures can be used for 10 years. The scrap value of the equipment and infrastructure is assumed to be 10% of their initial values.

Table 2
Total Investment Cost of a 800 Unit Farm

Investment	Cost (€)	%
Farming Equipments	*6,456,728*	*100.0%*
Smart units	2,612,800	76.6%
Moorings	3,102,400	18.9%
Eider duck fence	280,000	1.7%
Navigational markings	180,608	1.1%
Transport and delivery	19,000	0.1%
Installations	261,920	1.6%
Infrastructure for sea-work	*1,612,500*	*100.0%*
Working boat	1,000,000	62.0%
Small boat	100,000	6.2%
SmartScooter	460,000	28.5%
Spares, bruches, dewaterunit & assessories	40,000	2.5%
Transport and delivery	12,500	0.8%
Total investment cost	18,069,228	

4.2. *Operation cost*

It is estimated that three (3) employees are hired fully during a farming circle, even though some farming operation is carried out only by one person. A cycle of farming includes the following mandatory activities:

a) Preparing settlement

The 'Smart Farm system' is installed in the water at the first year and it is not needed removing from farming site after harvesting mussels. However, at the beginning of the farming cycle the farming system must be cleaned at the farming site before the settlement. The manpower cost of cleaning one unit is at 0.25 hour. The cleaning process is carried out by only one person. The man-hours for this work are 200 hours, plus 200 hours for running smart scooter and large boat.

b) Starfish removal

Starfish can eat a lot of mussels. Removing starfish is done once every growing season by using a machine in the large boat with soft brushes at high speed. Removing starfish takes around 0.125 hour per unit; in an extensive settlement this work can be done as fast as twice. The process of starfish removal is done by one person. Total manpower of starfish removal is 100 hours, plus 100 hours for running smart scooter and large boat.

c) Density control

If the seed of mussels attached to the lines with a high density, the mussels may not have enough feed to grow up to market size at the harvesting time. It is necessary to remove some mussel seed from the lines if its density is too high. Density control and starfish removal are done by the same machine. However, to reduce the seed density the machine needs a special equipment in-between brush sections. The reducing seed density takes about 0.25 hours per smart unit. The process can be done by three persons. Man-hour of density control is 600 hours, plus running hours of smart scooter and large boat 200 hours each.

d) Visual control

During the farming cycle, it is necessary to monitor the farming site, namely visual control. This activity can be carried out by one person, one day every second week during seven months of the farming circle. It is equivalent that the visual control takes 0.14 hour per smart unit. The man-hours of visual control are 112 hours for seven months.

The visual control is carried out by one person in a small boat. The running hours of the small boat are 112 hours.

e) Harvesting

The harvest of mussels happens at the end of the farming circle. The activity is carried out by the harvesting machine installed in the large vessel. The task is operated by three persons. The harvesting machine can harvest mussels in one smart unit in only one hour. Total time of harvesting is about 800 hours for an 800 smart units-farm, or equivalent to 100 days if harvesting eight hours/day. However, the harvesting can be done 24 hours pr. day, depending on market demand.

Total man-hours of harvesting mussels are 2,400 hours, plus running hours of the large boats and smart scooters of 800 hours each.

f) Annual technical survey

It is estimated that about 50% of the moorings has to be checked every year and man-hour of the checking is one hour per mooring, or equivalent to 0.5 hour per smart unit. This technical survey is carried out by two persons in a large boat, but the small boat is needed for commuting to the farming site and supporting the technical survey. Total man-hours of technical survey are 800 hours, plus running hours of large and small boats are 400 hours each.

g) Maintaining mooring and lines

The maintenance of moorings and lines is carried out every year at the beginning of the farming circle. It is estimated that 0.5 man-hour is needed for the maintaining of one smart unit and done by two persons. Both large and small boats are needed for the maintenance works. Total man-hours for the maintenance are 800 hours, plus 400 hours for running the large and small boat, respectively.

h) Safety margin and indirect cost

Safety margin and indirect cost are estimated at 10% of total man-power cost and cost of running boats and machine.

Table 3 shows the manpower cost of one year farming, and Appendix 2 presents the running hours of boats and equipments.

Table 3
Manpower Cost of Farming Activities

Activities	Hours pr. smart unit	Hours of running boats & equipment	Number of persons	Total man-hours
1. Preparing settlement	0.25	200	1	200
2. Starfish removal	0.125	100	1	100
3. Density control	0.25	200	3	600
4. Visual control	0.14	112	1	112
5. Harvesting	1	800	3	2400
6. Yearly technical survey	0.5	400	2	800
7. Maintaining lines, moorings & tensioning	0.5	400	2	800
8. Safety margin & indirect time (10%)		251	2	501
Total hours		***2,463***		***5,513***

The cost of manpower will be calculated by man-hours and labour cost (35€/h). The running costs of equipments and boats are calculated by multiplying running hours with respective running unit cost. The running unit cost of equipment and boat covers mainly the cost of the gasoline. It is estimated that a cost of 45,000€ is needed each year for the materials and necessary material input for running boats and farming equipment.

4.3. Total cost

Total cost for operating the farm annually includes variable cost and fixed cost. The variable cost includes the cost of manpower for farming activities and cost of material input including energy for running boats and farming equipment.

The total operation cost is calculated and presented in Table 4, which consists of the following cost components:

- Manpower cost: 5,513hour x 35€/hour=192,962€/year
- Running costs of boats and equipment are calculated based on the running hours of the boat and equipment plus €45,000 each year for materials expense. Running costs of boat and equipment are 248,628 €/year.
- Maintaining costs are calculated as 1% of total cost of boats & equipment investment, and 0.1% cost of farming system investment.

- The insurance cost is assumed as 1.5% of the total investment cost.
- The cost of administration is 80,000€/year assuming one person is needed for this work;
- The office cost is calculated as 40,000€/year.
- It is estimated that the farmer needs a loan of 1 €million each year for operation. The interest of the loan is 60,000/year (6%).

Table 4
Total Operation Cost of One Farming Circle

Operation Cost	*Euro (€)*
Cost of man powers	192,962
Running costs of boat & equipments	248,628
Total variable cost	*441,590*
Maintaining boats & equipment	16,125
Maintaining farm	16,457
Insurance (1.5%)	271,038
Manpower admin & lead	80,000
Office & other fixed costs	40,000
Interest of working capital	60,000
Total operational cost	*925,210*

The total operation cost of an 800 unit farm is 925,210€/year, which provides an average operation cost of 1,156.51€/unit. However, the variable cost for one farm unit is only at 552€.

5. Revenue

As outlined in Section 3 there are three products that can generate revenue for the farm: 1) Mini-mussels for consumption 2) Input for fishmeal production and 3) Environmental service in the form of filtration and reducing pollutant. The production of these three products will supplement each other, that is, there will be joint production. There is at present no market for any of the products and the revenues have therefore to be established from theoretical considerations. It is assumed that 20% of the production is used for direct human consumption in the form of mini-mussels; the remaining 80% of the production is supplied as raw material for fishmeal products. It is also assumed that harvested mussel contains about 1% Nitrogen and 0.1% Phosphorus (P) (Odd Lindahl 2012).

Mini-mussels for consumption

There are several reference prices for mussels supplied to human consumption. For example, we estimated that the average auction price of raw material mussels in the Netherland over the past 10 years is 1.27€/kg (with a standard deviation of 0.72). Another, based on the demand analysis of Thong (2012) we know that the elasticity of Danish mussels is of -1.08, we estimate that the price of 20,000 ton mussel per year is 0.83€/kg/farm. Third, the average price of wild stock mussels of Denmark during the period of 2002-2008 is 0.195€/kg, however, this price is before cleaning and sorting, they have a low recovery and the main product is caned and cooked mussels. We apply the price of 0.83€/kg as the mini mussels are expected to be sold as fresh food in the market.

Input to the fishmeal industry

The price for fish meal is around 2.0 €/kg, however, the fishmeal from mussel has competitive advances as feed for trout, salmon and hens, as it increases the colour of fish meat and egg yolk. It is therefore expected that the mussel meal can get around 3 €/kg. The processing cost of making 1 kg of mussel meal is between 0.5 and 1 Euro and the recovery is only 5 % (weight) (Odd Lindahl 2012). Summing up, the meal producer can only pay around 0.1€ kg for mussels input.

Environmental benefit

Mussel farmers can deliver the service of removal of nutrient and filtering to either the aquaculture or agriculture. It is estimated that it costs around 10 to 30 € to subtract one kg of Nitrogen in the sea, if the reduction has to be done in the agriculture. This means that mussel farmers will have a value of between 0.1 and 0.3 € per kg mussel harvest. There is, however, no market for this service; a mussel farm in the Great Belt will clean the water that originates from the Baltic Sea, and the run off stems from the many countries around the Baltic Sea. It will be difficult to get payment from the polluters directly. A possibility can be the Danish government paying for the service, but there are no precedents for this. The best option seems to be to supply the service to a fish farm. Here there will be an additional benefit as the mussel will benefit from the fish feed not captured by the farmed fish, hence have increased growth. What the benefit of the cleaning service is to the fish farm will depend on the abatement standards. We will use the known value of 0.2 € per kg mussel, but note that the value for a fish farm probably will be higher.

In sum, we estimate that mini mussel farmers will supply 80% of their production to reduction for mussel meal and get paid of 0.1€/kg fresh mussel and 20% production supplied to seafood processing factories and get paid of 0.83€/kg. In addition, the mussel farmers also get paid 0.2€ for each kg mussel produced from fish farmers and polluters. The expected average price of mussels in this project is therefore estimated at 0.446€/kg.

If mussel farmers cannot get paid their environmental contribution, the expected price is only 0.246€/kg.

The smart-farm system is a mess-size form formulated by both vertical and horizontal ropes, which can facilitate the mussels attaching. A 240 mm mess-size creates 6,067 m of length of rope (vertical and horizontal dimensions) for a smart unit. The total length of a farm of 800 units is 4,853,600m, which facilitates as 'living space' for mussel growth.

It is estimated that about 4.15kg mussels will be harvested from 1 m of rope length. The total production volume is over 20,000 tonnes of mussels per farm per year. The lost ratio during transportation is assumed at 25%.

6. Profitability

6.1. Annual profit and net present value (NPV)

Table 5 presents the revenue and profit of the project for one year of farming. The total revenue of each year is about 6.7 €M, profit before income tax is 4.0 €M, and the net profit is 3.2 €M each year. Using interest rate of 6%, the net present value (NPV) of the project is 19.8 €M and the internal rate of return (IRR) of the project is 25.0%. The project can get full investment return at the end of year four. The project will get zero profit (break-even point (BEP)) when expected price falls down to 0.223€/kg or productivity deceases to 2.08kg/m while other factors are constant. This price is much lower than the optimal price used in the project and the price in the auction market of the Netherland. However, the price is higher than the current price of wild stock mussels of Denmark.

Table 5
Profit of One Year Farming

Revenue and cost	Unit
Total production volume (kg)	20,142,440
Lost volume in transport (25%)	5,035,610
Net production volume	15,106,830
Expected price (€/kg)	0.446
Revenue (€)	*6,737,646*
Operation cost	925,210
Yearly fixed cost	*483,620*
Variable cost	*441,590*
Depreciation (10%)	1,806,923
Total cost (€)	2,732,133
Profit before income tax	4,005,514
Income tax (20%)	801,103
Net profit (€)	3,204,411
Net present value (NPV)	*19,823,601*
Internal Return Rate	*25.0%*
Expected price at BEP	*0.223€/kg*
Productivity at BEP	*2.08kg/m*

If the mussel farmers don't get paid from fish farmers and polluters, the selling price is only 0.246€/kg. This price is still higher than the BEP price. However, the NPV is only at 2.03 €M and IRR is about 8.2%.

6.2. Sensitivity Analysis

Even though the profitability of the project is well established the conditions may be changed due to many unforeseeable changes in key parameters. The risk and uncertainty which must be assessed further is:

- *Price of selling mussels*: Mini mussel is a new product and the consumer's preference for this mussel has not been tested. The price at farm gate is one of the most important factors determining the project profitability.

- *Productivity*: It is assumed that each metre of smart-farm rope can produce 4.15 kg mussels. However, this productivity may vary due to environmental risk factors such as storms, nutrition's density, mussel-seed availability, mussels eaten by starfish & Eider duck, ect. These factors can impact the productivity.
- *The variable cost (including manpower and running boat & equipment cost):* The labour cost accounts for a large part of the production cost in traditional farming system. However, the smart-farm is not a labour intensive production method. The variable cost accounts for only 16% of total cost. The variable cost is the least uncertain factor.
- *Cost of smart-farm units, equipment and boats:* These costs account for a large part of investment, but they are fixed and can be estimated at the beginning of the project.
- *Farm scale variation:* Because investment costs account for the largest part of the total cost in a smart-farm, the profitability of the project depends significantly on the scale of a farm. The project is suggested for a farm of 800 units, which is based on the feasible conditions presented above. However, the infrastructure investment, which accounts for a large part of total investment cost, can be used for different farms.

We will assess the profitability of the project according to different scenarios that take into account the risk and uncertainty factors presented above separately and simultaneously.

a) Price variation

The selling price of the produced farm mussels is the most uncertain factor affecting the profitability of the project. We use an expected price of 0.446€/kg that is estimated by our research and we found the project highly profitable. However, there is no guarantee that the farmers will get this price all the time. Figure 4 presents the NPV and IRR estimated at different selling prices.

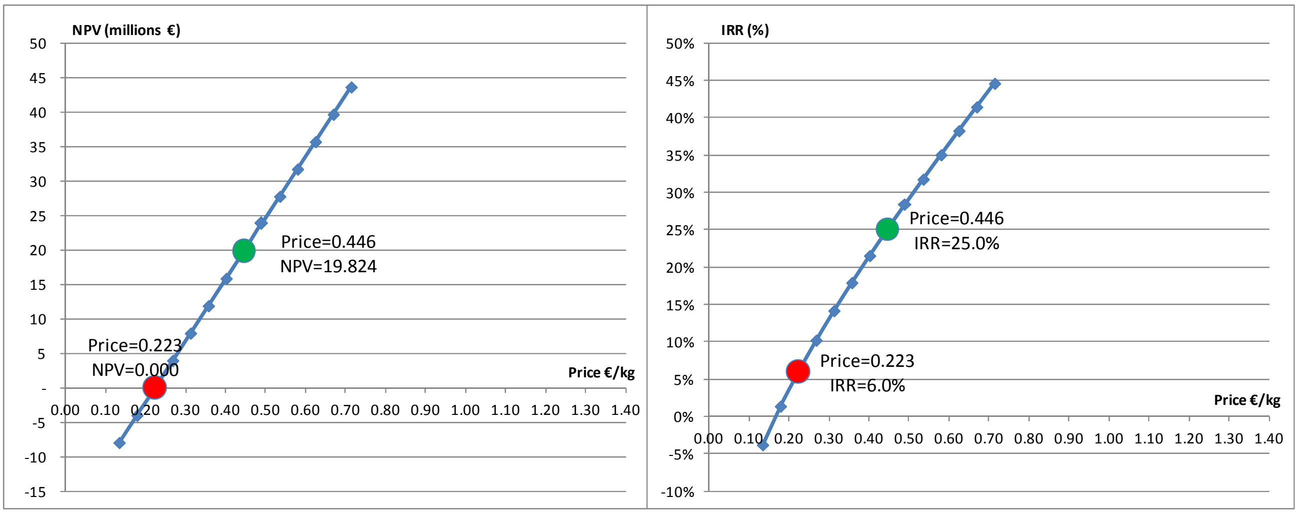

Figure 4: The project profitability at different selling price

With the discount rate of 6% per year and the selling price of 0.446€/kg, the project will have the net present value (NPV) of 19.8M€ and internal return rate (IRR) of 25%. The brake-even point is reached at 50% of expected price or 0.223€/kg, where the NPV is zero and IRR is at the discount rate of 6%. However, this minimum price is unlikely because we expect that mussel farmers will be get paid of 0.2€/kg mussel produced from fish farmers and government for its environmental benefit performed. Therefore, the expected price falls down to 0.223€/kg only when both selling prices of fresh mussels to fish meal producers and seafood factories decrease by 80% of the proposed price of the project.

b) Productivity variation

Productivity of a farm is an uncertain factor because of seed supply or predation by ducks, seagulls, and crabs. Other environmental conditions also impact on the mussel density and growth.

Figure 5 presents the NPV and IRR of the project at different scenarios of varying productivity.

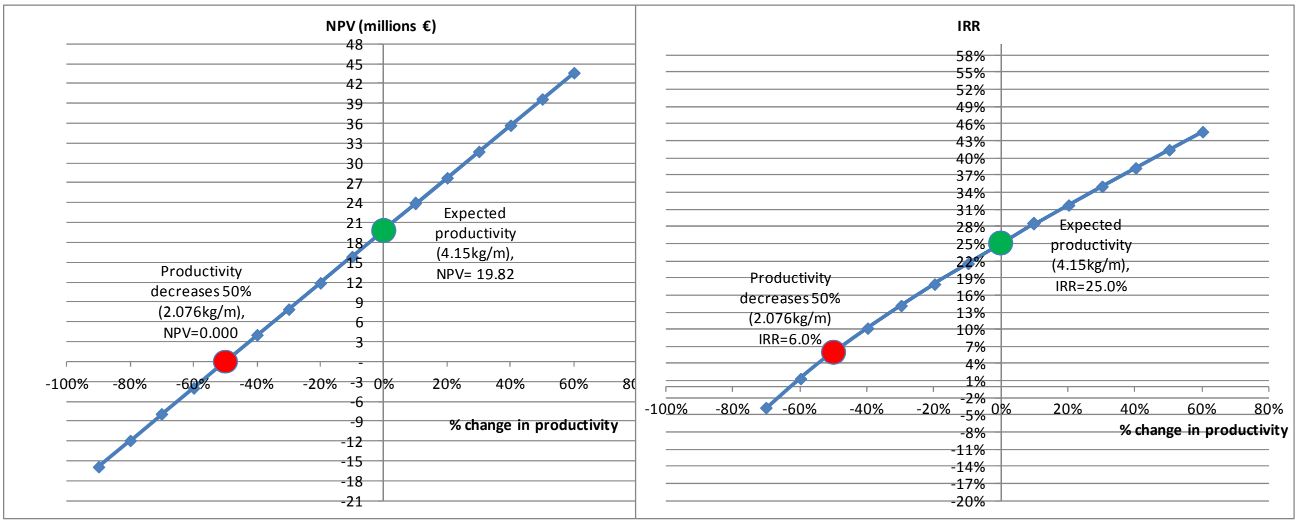

Figure 5: Project profitability with productivity variation

The project will have zero profit when the farming productivity is reduced by 50% from the expected productivity level (4.15kg/m). In other words, the project will not be profitable (at 6% discount rate) if the farm produces less than 2.076kg mussels per metre of rope.

c) Simultaneous variation of price and productivity

We estimate the NPV and IRR of the project with simultaneous variation of selling price and productivity, which are the most determinant factors of the project success. Appendix 3 presents the NPV and IRR for different scenarios of price and productivity. To have positive NPV (IRR above 6%), the price of fresh mussels must not fall down below 50% of expected price (0.446€/kg) while productivity and other factors are constant. Similarly, the productivity must not be lower than 50% of the expected productivity (4.15kg/m) while price and other factors are constant.

d) Chance of success of the project under all uncertain factors

We consider simultaneously the impact of all uncertainty factors on the project profitability. That include, price of mussels, productivity, prices of Smart Farm unit, infrastructures, installation cost, and manpower unit cost. We apply Monte Carlo analysis, and the assumptions of the uncertainty factors are presented in Appendix 4.

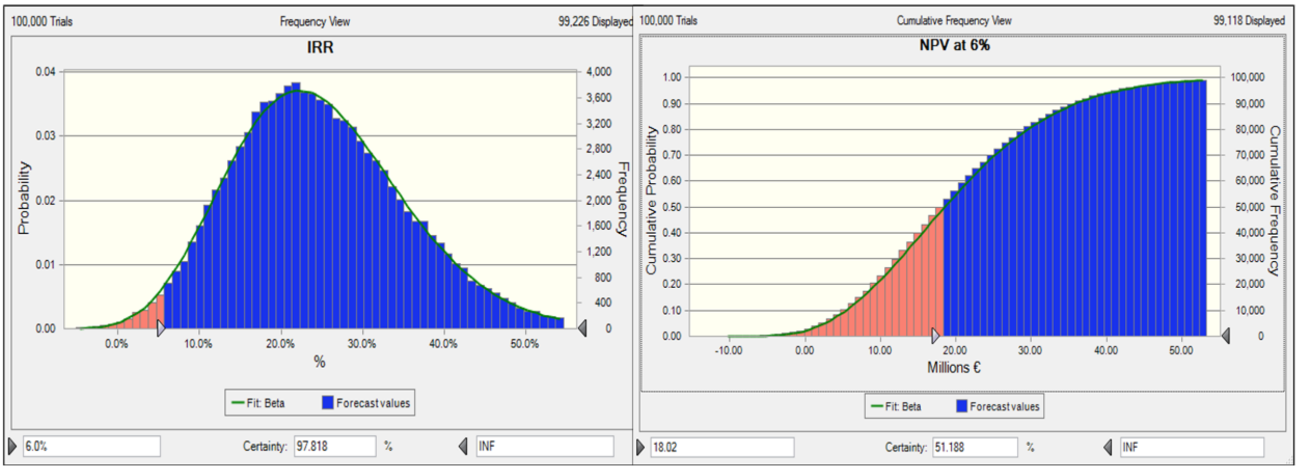

Figure 6: Simulation of profitability under uncertainties of productivity and input factors

As presented in Figure 6, the project has 97.8% probability of success (positive NPV or IRR above 6%), based on 100,000 trial simulations. This probability is quite high. Above 50% probability that the project will have NPV within 18-65m€.The productivity and price of mussels (especially price of mussels supplied to mussel meal producers) are the most important factors determining the success of the project.

We also assess the case that mussel farmers will not get paid from fish farmers and polluters for their environmental contribution. This leads to the expected price of mussels is at only 0.246€/kg. This selling price is above the price at break-even point. This means the project still have profit even though the farmers are not subsidized. The NPV for this situation is 2.03 M€ and IRR is 8.2%. However, the probability of the project success is only 52.9%.

e) Scale variation

Expenses of infrastructure for sea-work account for 10% of the total investment and administration fixed costs account for 20% total operating cost. The two expenses are dependent on the size of the farm and may provide the scale economics for the project. We assess the profitability of the project when varying farm size.

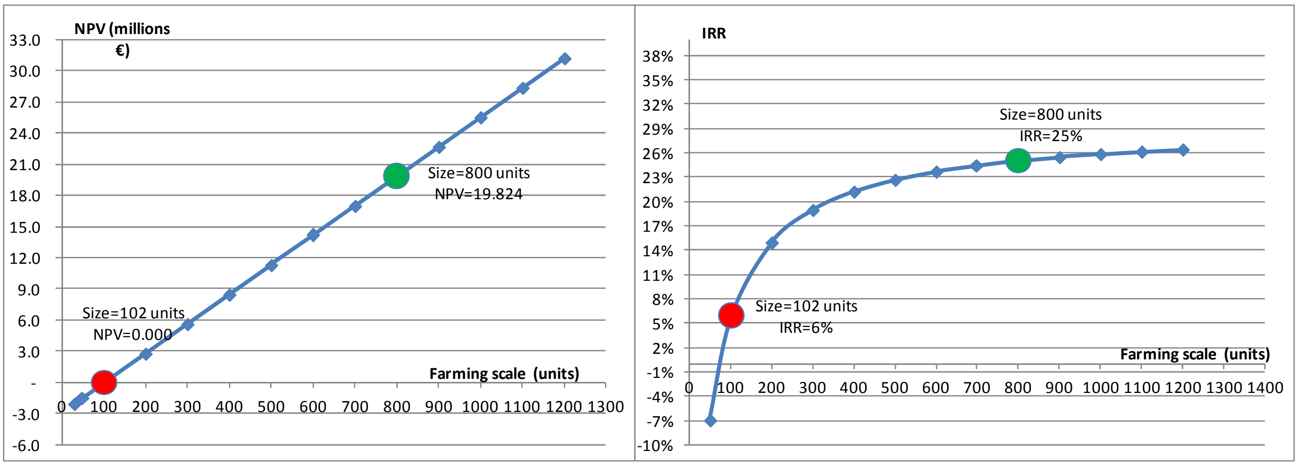

Figure 7: The project profitability at different farming scales

Figure 7 presents NPV at discount 6% and IRR of the project at different farm scales. It suggests that a farm should have a size above 102 Smart Farm units. The farm that size below 102 units will have negative NPV and IRR lower than 6%.

7. Conclusions

We assessed the financial feasibility of farming mini mussels (length of 35mm) in the Great Belt of Denmark within a short period (7-8 months). The less labour intensive cost farming system can overcome the obstacles of traditional mussel farming system in the Nordic countries. The project is carried out for ten years and has high profitability with NPV of 19.8 €M for a farm that can produce 20,000 tons of fresh mussels per year. We estimated that the Great Belt can produce totally 200,000 fresh mini mussels annually; hence 10 farms can exploit the capacity of the Belt.

Mini mussels are a new product and so is mussel meal as feed for fish and poultry. This means that a mussel farm cannot depend on a market for their products but actively have to create the market themselves. This clearly adds a great deal of uncertainty to the profitability. If the fish farms in the Great Belt want to expand production, they will need the services from the mussel farms to clean fish feed and faece particles out of suspension. It is our recommendation that the mussel farms depart from this demand, either as part of the fish farm or in close corporation with a fish farm, and secure the existents of this market and the price. If this price is close to the BEP, the project will have high chance of profitability, even in the case that the total mussel production is used for meal production with no premium price. By constructing the mussel farm with the 'Smart Farm system' the option for creating a market for the mini-mussel will be present and can be explored.

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Appendix

Appendix 1
Unit Price of Farming System and Equipments

Product descriptions	Unit price (€)	Unit
Smart-units	15,766	unit
Mooring for units	3,878	set
Navigational markings	2,822	set/unit
Accessories and sparepacts	35,000	unit
Smart scooters	457,600	unit
Mooring assistance	625	pr. Person/day
Transport & delivery	9,500	pr. one transport (two transportations for 800 units)
Installation	327.4	€/unit
Eider duck fence	35	m (80m/unit)

Source: Smart-farm company, Norway

Appendix 2
Running Hours of Boats and Equipments

Activities	Running hours of Smart Scooter	Running hours of Large vessel	Running hours of Small boat
Preparing settlement	200	200	
Starfish removal	100	100	
Density control	200	200	
Harvesting	800	800	
Visual control			112
Yearly technical survey		400	400
Maintaining lines, moorings & tensioning		400	400
Safety margin & indirect time (10%)			251
Total hours	1,300	2,100	1,163

Appendix 3

	NPV (m€)	Price variation																
		-80%	-70%	-60%	-50%	-40%	-30%	-20%	-10%	0%	10%	20%	30%	40%	50%	60%	70%	80%
Productivity variation	-90%	-19.1	-18.7	-18.3	-17.9	-17.5	-17.1	-16.7	-16.3	-15.9	-15.5	-15.1	-14.7	-14.3	-13.9	-13.5	-13.1	-12.7
	-80%	-18.3	-17.5	-16.7	-15.9	-15.1	-14.3	-13.5	-12.7	-11.9	-11.1	-10.3	-9.5	-8.7	-7.9	-7.2	-6.4	-5.6
	-70%	-17.5	-16.3	-15.1	-13.9	-12.7	-11.5	-10.3	-9.1	-7.9	-6.8	-5.6	-4.4	-3.2	-2.0	-0.8	0.4	1.6
	-50%	-16.7	-15.1	-13.5	-11.9	-10.3	-8.7	-7.2	-5.6	-4.0	-2.4	-0.8	0.8	2.4	4.0	5.5	7.1	8.7
	-40%	-15.9	-13.9	-11.9	-9.9	-7.9	-6.0	-4.0	-2.0	0.0	2.0	4.0	6.0	7.9	9.9	11.9	13.9	15.9
	-30%	-15.1	-12.7	-10.3	-7.9	-5.6	-3.2	-0.8	1.6	4.0	6.3	8.7	11.1	13.5	15.9	18.2	20.6	23.0
	-20%	-14.3	-11.5	-8.7	-6.0	-3.2	-0.4	2.4	5.1	7.9	10.7	13.5	16.3	19.0	21.8	24.6	27.4	30.1
	-10%	-13.5	-10.3	-7.2	-4.0	-0.8	2.4	5.5	8.7	11.9	15.1	18.2	21.4	24.6	27.8	30.9	34.1	37.3
	0%	-12.7	-9.1	-5.6	-2.0	1.6	5.1	8.7	12.3	15.9	19.4	23.0	26.6	30.1	33.7	37.3	40.8	44.4
	10%	-11.9	-7.9	-4.0	0.0	4.0	7.9	11.9	15.9	19.8	23.8	27.8	31.7	35.7	39.7	43.6	47.6	51.6
	20%	-11.1	-6.8	-2.4	2.0	6.3	10.7	15.1	19.4	23.8	28.2	32.5	36.9	41.2	45.6	50.0	54.3	58.7
	30%	-10.3	-5.6	-0.8	4.0	8.7	13.5	18.2	23.0	27.8	32.5	37.3	42.0	46.8	51.6	56.3	61.1	65.8
	40%	-9.5	-4.4	0.8	6.0	11.1	16.3	21.4	26.6	31.7	36.9	42.0	47.2	52.4	57.5	62.7	67.8	73.0
	50%	-8.7	-3.2	2.4	7.9	13.5	19.0	24.6	30.1	35.7	41.2	46.8	52.4	57.9	63.5	69.0	74.6	80.1
	60%	-7.9	-2.0	4.0	9.9	15.9	21.8	27.8	33.7	39.7	45.6	51.6	57.5	63.5	69.4	75.4	81.3	87.3

IRR																	
-90%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-80%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-70%	-	-	-	-	-	-	-	-	-	-	-	1%	2%	4%	5%	6%	8%
-60%	-	-	-	-	-	-	-	-	1%	3%	5%	7%	9%	10%	12%	13%	15%
-50%	-	-	-	-	-	-	1%	4%	6%	8%	10%	12%	14%	16%	18%	20%	22%
-40%	-	-	-	-	-	2%	5%	8%	10%	13%	15%	17%	19%	22%	24%	26%	28%
-30%	-	-	-	-	2%	6%	9%	11%	14%	17%	19%	22%	24%	27%	29%	31%	34%
-20%	-	-	-	1%	5%	9%	12%	15%	18%	21%	24%	26%	29%	32%	34%	37%	40%
-10%	-	-	-	4%	8%	11%	15%	18%	22%	25%	28%	31%	34%	37%	40%	42%	45%
0%	-	-	1%	6%	10%	14%	18%	22%	25%	28%	32%	35%	38%	41%	45%	48%	51%
10%	-	-	3%	8%	13%	17%	21%	25%	28%	32%	36%	39%	43%	46%	50%	53%	56%
20%	-	-	5%	10%	15%	19%	24%	28%	32%	36%	40%	43%	47%	51%	55%	58%	62%
30%	-	1%	7%	12%	17%	22%	26%	31%	35%	39%	43%	47%	51%	55%	59%	63%	67%
40%	-	2%	9%	14%	19%	24%	29%	34%	38%	43%	47%	51%	56%	60%	64%	69%	73%
50%	-	4%	10%	16%	22%	27%	32%	37%	41%	46%	51%	55%	60%	65%	69%	74%	78%
60%	-	5%	12%	18%	24%	29%	34%	40%	45%	50%	55%	59%	64%	69%	74%	79%	84%

NPV and IRR of the project with varying price and productivity

Appendix 4

Assumptions of analyzing chance of success of the project

Uncertain Factors	Mean	Std.dev
Price from fish meal producers	0.1	0.02 (20% mean)
Price from seafood processors	0.83	0.17 (20% mean)
Productivity	4.15	0.82 (20% mean)
Lost ratio	0.25	0.025 (10% mean)
Labour cost (€/hour)	35	3.5 (10% mean)
Running cost for large vessel (€/hour)	51	5.1 (10% mean)
Running cost for SmartScooter (€/hour)	51	5.1 (10% mean)
Running cost for small boat (€/hour)	26	2.6 (10% mean)
Price of Smart-units (€/unit)	15,766	1576.6 (10% mean)
Price of mooring for units (€/set)	3,878	387.8 (10% mean)
Price of navigational markings (€/set unit)	2,822	282.2 (10% mean)
Price of accessories and sparepacts (€/unit)	35,000	3500 (10% mean)
Price of smart scooters (€/unit)	457,600	45760 (10% mean)
Price of mooring assistance (€/person)	625	62.5 (10% mean)
Price of mobilization (€/delivery)	9,445	944.5 (10% mean)
Price of Eider duck fence (€/m)	35	3.5 (10% mean)
Installation	327.4	32.74 (10% mean)
% production used for fish meal (uniform distribution)	60% to 100%	

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