AKVATECH

Sustainable Aquaculture

Iceland

17 January 2014

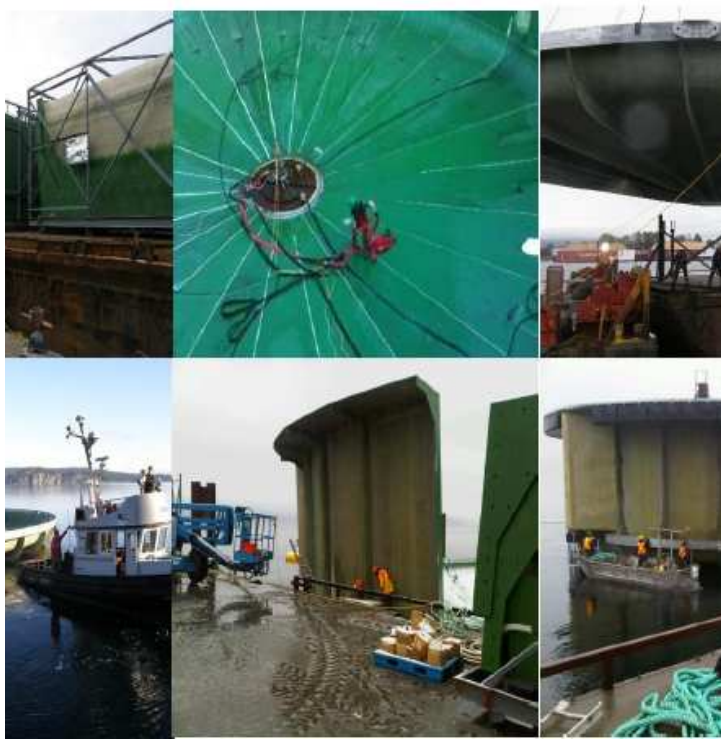
A leading supplier of technology and solutions to the aquaculture industry

Vision

The Company's vision is to become a leading supplier of innovative and sustainable solutions to the aquaculture industry.

We shall contribute to the further development of profitable and environmentally friendly aquaculture operations by delivering transformational technology and solutions that

- improves the feed conversion ratio
- prevents fish escapes
- eliminates fish feces and waste feed pollution of the surrounding ecosystems
- reduces the risk of sea lice infestation
- maximizes fish health



Technology development

R&D Land-based closed containment operation 2001 - 2005

R&D Floating closed containment operation 2005 - 2009

Full-scale deployment of the AgriMarine SystemTM in China, pilot in BC, Canada 2009 - 2011

Commercial salmon production in China and Canada 2012 -

AgriMarine has spent more than 15 million US$ in R&D and testing of solid-wall containment technology over the last decade. Since 2010, Akvatech has in collaboration with AgriMarine been working on commercializing the AgriMarine SystemTM.

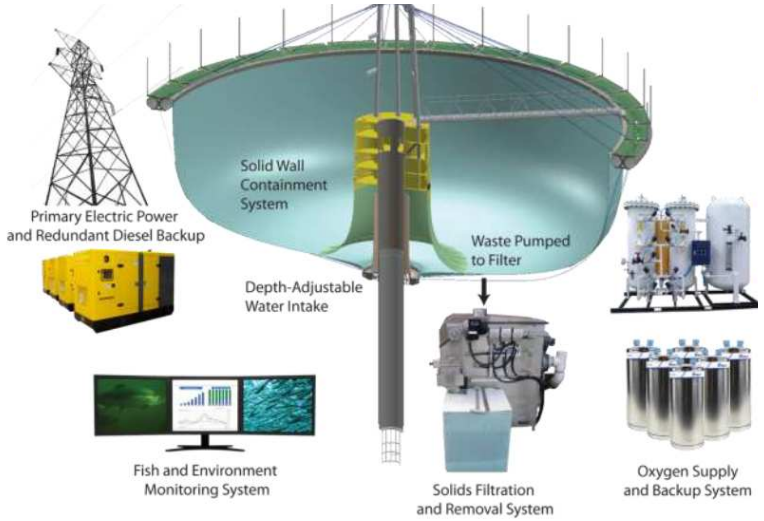
Akvatech holds the exclusive rights to develop and sell the AgriMarine SystemTM in Northern Europe.

Technology

Features

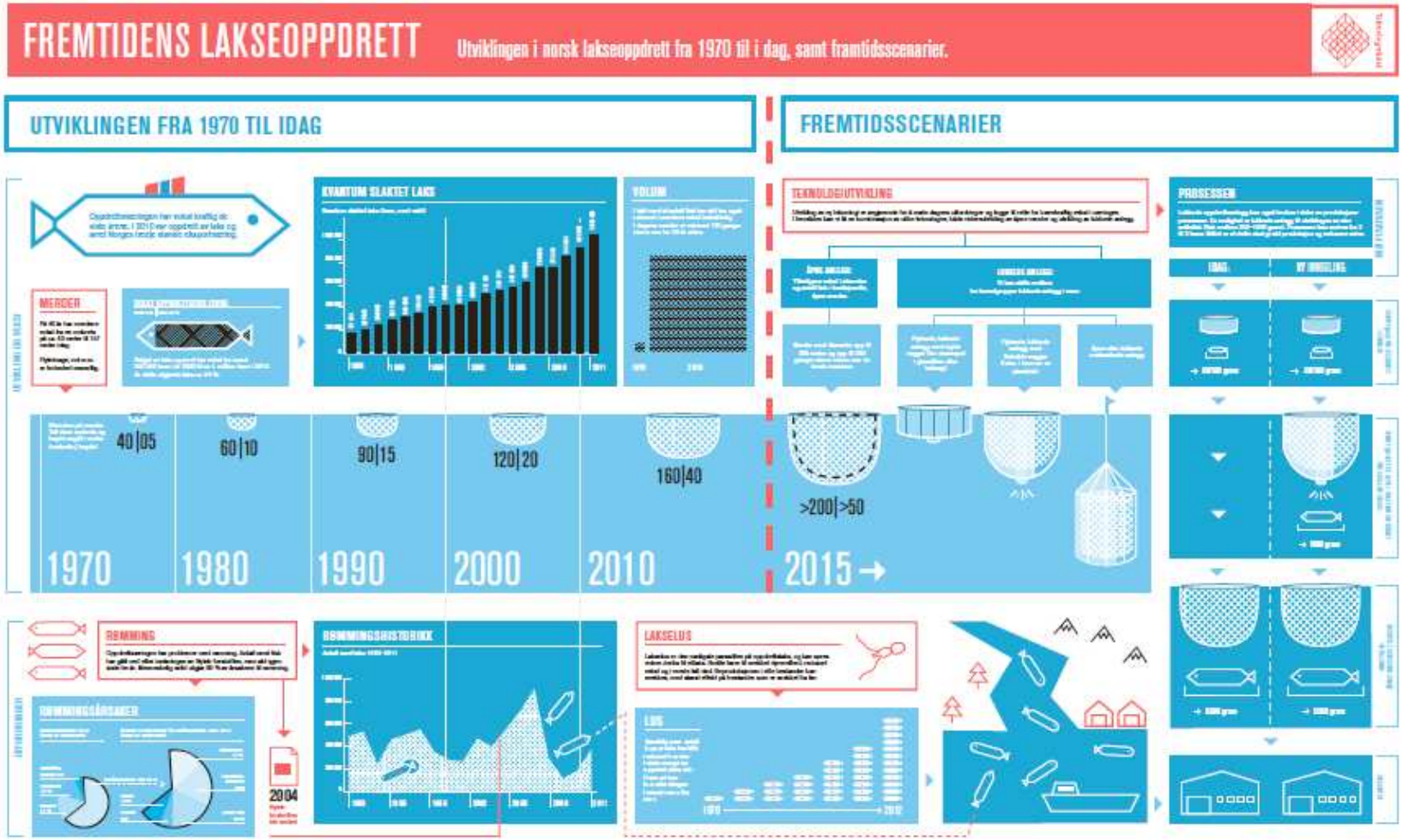
- **System integrity**
  Meets increased focus on the environmental impacts of current fish farming practices
- **Shipment costs**
  Parts designed to fit into common shipping containers
- **Increased efficiency in waste capture**
- **Better operational control**
  Real-time monitoring and adjustment of water temperature and oxygen level - efficient pumping system with variable depth water intake and oxygen generating system

Hoved komponenter



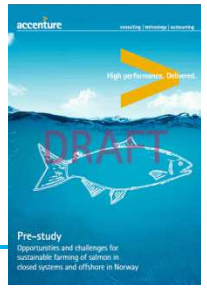
Floating solid-wall fish tanks that marries the environmental benefits of land-based closed containment with the low cost production of net cage salmon farms

Teknologirådet – fremtidens lakseoppdrett



Source: Teknologirådet 2012

Accenture / WWF



Overview and Assessment of New Salmon Farming Technologies

Accenture has mapped projects, both in Norway and globally, for each of the three technologies considered in this report:

Recirculation aquaculture systems (RAS) | Open containment systems with offshore net pens | Closed containment systems with coastal cages

Future salmon aquaculture production technology in Norway

Thus far, the industry in Norway has been able to grow by increasing the number of biomass licences and locations. Presently, however, the availability of locations has become a limiting factor, and Norwegian authorities have placed restrictions on the allocation of new biomass licences. Consequently, the most effective alternatives for achieving industry growth are by optimising existing technology or by developing new production technologies. Losses in the production process due to escape, disease, sea lice, and mortality have direct economic impacts as well as environmental impacts. Shorter production time in open net pens allows for greater flexibility in the management of seawater biomass licences. Reducing production time in seawater could therefore further reduce the risk of losses and

Map of Norwegian and global projects

Figure 3: Map of Norwegian and global projects for land-based recirculation aquaculture systems, open offshore systems and closed coastal systems*

* Though not exhaustive, this map provides an overview of many of the projects in the area; from planning and full-scale pilots to commercialised farms. Further details on each of the projects can be found in the appendix, chapters 9.3 and 9.4.

Global projects
RAS technology has a relatively global spread whereas, by contrast, only a limited number of projects for open offshore systems and closed coastal systems were identified in the course of this study.

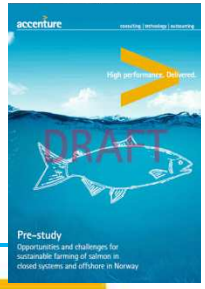
in Canada, the United States, Denmark, China, and Chile.

Accenture found no projects for open offshore systems, and the use of closed coastal systems was found to be lim-

Norwegian projects
In Norway, most projects are in the research and development phase. RAS has been piloted for extended smolt production and holding cages. Offshore cage technology is still immature, as there

Source: Accenture / WWF 2013, 2014

Accenture / WWF

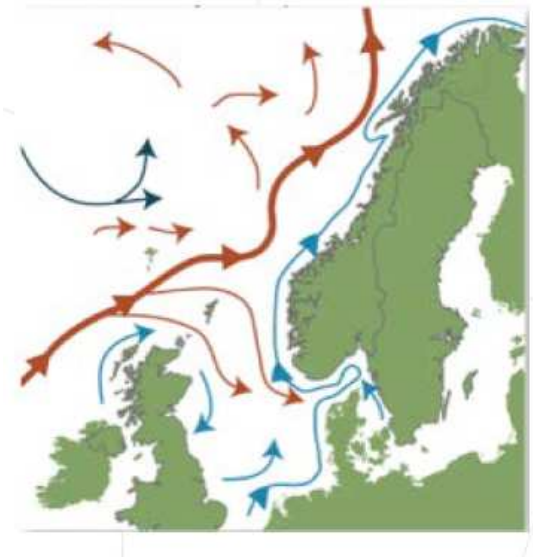


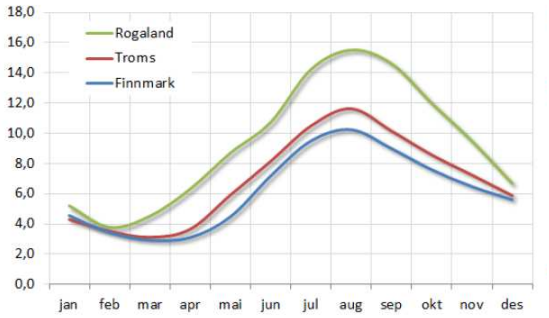
Parameters	Weight	Open	Closed	RAS	Extended shelf
Escapes	High	1 - Many escapes incidences in the past - System relatively sensitive to weather conditions - High probability of net holes	4 + Impenetrable walls and secured filtering systems prevent escapes + The problem of holes and wear on nets is avoided - Relative movement of water inside the construction can toss fish out of the system (Sintef = 2) - Possible escapes related to water pumping and construction crews (2)	6 + The system is placed onshore (no currents, little or no risk related to weather conditions and boat traffic) - Still possible to have structural collapse or breakdown of water filtering	2 + Same as closed coastal system up top 1kg (reduced time in open nets) - Same as open system after 1kg
Lice	High	1 - Open nets do not prevent lice from entering the system - The system uses surface water which contains relatively high amounts of lice compared to water from deeper sea levels	4 + Water can be filtered and disinfected in and out of the system + Water can be pumped from depths where there is less lice - Filtering system and water pumps can break down - Reduced water flow (sintef) and increased density can increase infection rates - Surface water containing lice can splash into the system	6 + Water can be filtered and disinfected in and out of the system + Water can be pumped from depths where there is less lice + Only inlet for lice is through the filtered water intake which only counts for 1.0% of the water consumption	2 + Same as closed coastal system up top 1kg (reduced time in open nets) - Same as open system after 1kg
Fish welfare	Medium	2 - Relatively high mortality rates in early smolt stages - Possible consolidation against the nets - Not possible to control water temperature - Open nets do not prevent spread of viruses	4 + Water flow and oxygen levels can be controlled + Filtering water intake can prevent the intake of viruses + Regulations for water quality can possibly assure equally good water quality as in open systems (tickn.nå) - Water from deeper sea levels can affect growth patterns and growth rates (tickn.nå) - Water from deeper sea levels can cause new diseases (tickn.nå) - Increased fish density increases the risk that infections will spread and might increase stress	4 + Possible to control water temperature, water flow and oxygen levels + Filtering water intake and recycling of water can prevent the intake/reduce spread of viruses + Regulations for water quality can possibly assure equally good water quality as in open systems (tickn.nå) - Water from deeper sea levels can affect growth patterns and growth rate (tickn.nå) - Water from deeper sea levels can cause new diseases (tickn.nå) - Increased fish density increases the risk that infections will spread	3 + Same as closed coastal system up top 1kg (reduced time in open nets) - Same as open system after 1kg
Climatic effects	Low	4 + No water pumping reduces energy consumption - Emissions related to transportation	2 +/- Retained biomass can be used to produce energy, but as of today we lack the necessary infrastructure - Energy consumption related to water pumping water, add oxygen, collect waste and recycle the waste - Emissions related to transportation - Extra energy will be used if the water is filtered (tickn.nå)	1 +/- Retained biomass can be used to produce energy, but as of today we lack the necessary infrastructure + Less transportation/ logistics - Energy used to pump water, add oxygen, heat/cool water, recycle water, collect waste and recycle the waste - Extra energy consumption needed for water pumping since the system is above sea level - Extra energy will be used	3 + Same as closed coastal system up top 1kg (reduced time in open nets) - Same as open system after 1kg

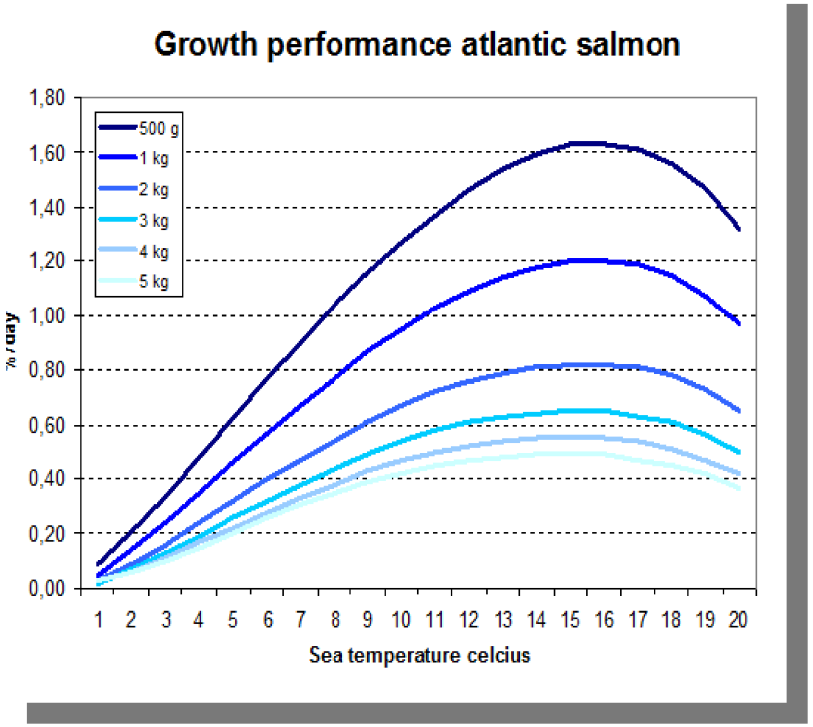
Parameters	Weight	Open	Closed	RAS	Extended shelf
Direct pollutants / chemicals	Medium	1 - High risk of lice means more use of drugs and delousing substances - Copper used to impregnate the nets	2 + Less risk of lice means less use of medication and delousing substances + Food containing medication is collected + Filtering can reduce emission of delousing substances - Some substances can escape through the filtering system, and the filtering system can break down	4 + Less risk of lice means less use of medication and delousing substances + Food containing medication is collected + Filtering can reduce emission of delousing substances + Not in immediate contact with water - Some substances can escape through the filtering system, and the filtering system can break down	2 + Same as closed coastal system up top 1kg (reduced time in open nets) - Same as open system after 1kg
Discharges of nutrient salts and organic materials	Low	1 - Open nets does not prevent organic and nutrients emissions	4 + Feces, waste food and filtered mass can be collected which leads to less nutrients and organic emissions (if deposited elsewhere) +/- Retained biomass can be used to produce energy, but as of today we lack the necessary infrastructure	6 + Feces, waste food and filtered mass can be collected which leads to less nutrients and organic emissions (if deposited elsewhere) +/- Retained biomass can be used to produce energy, but as of today we lack the necessary infrastructure + Not in immediate contact with sea water	2 + Same as closed coastal system up top 1kg (reduced time in open nets) - Same as open system after 1kg
Zoning	Low	3 - Claims sea acreage	4 - Claims sea acreage + Can take new and remote areas into use (arctic where conditions are too poor to use open systems) + Higher MAED can lead to less space needed per MAB (given same pen depth)	1 - Claims land acreage - High conflicts of interest on the Norwegian shore - More space needed in absolute terms (housing around pens) - Opportunity cost more relevant than in sea - More space needed in due to more shallow pens (source?)	3 - Claims sea acreage - The extra closed system is assumed to be placed close to the open net pens and will not claim an additional location. The marginal impact is assumed to be small.
Input factors in construction of system	Low	4 + The open containment system is the least complex construction and requires the least amount of materials in production + Relatively simple production process leads to modest energy consumption	2 - The coastal closed cages are based on a sturdier construction than open pens and the systems involve water pumping and filtering components. Consequently coastal closed cages consume more materials and energy during production compared to open pens	1 - RAS systems are the most complex construction (in addition to onshore tanks RAS requires housing, filtering systems, recirculation systems, pumping facilities etc.) and requires the most amount of materials and energy in production	3 + Part of the production happens in open pens - Part of the production is done in closed coastal cages
Σ		1.8	3.0	3.8	2.4

Source: Accenture / WWF 2013, 2014

Temperature



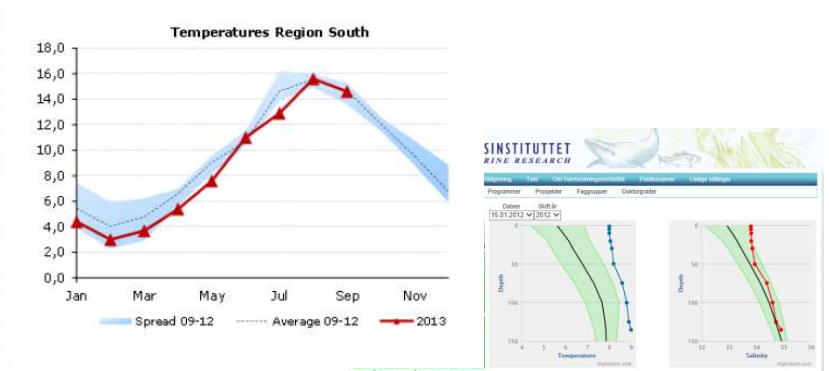




The average yearly temperature difference between the northern and southern parts of Norway is 3 degrees Celsius

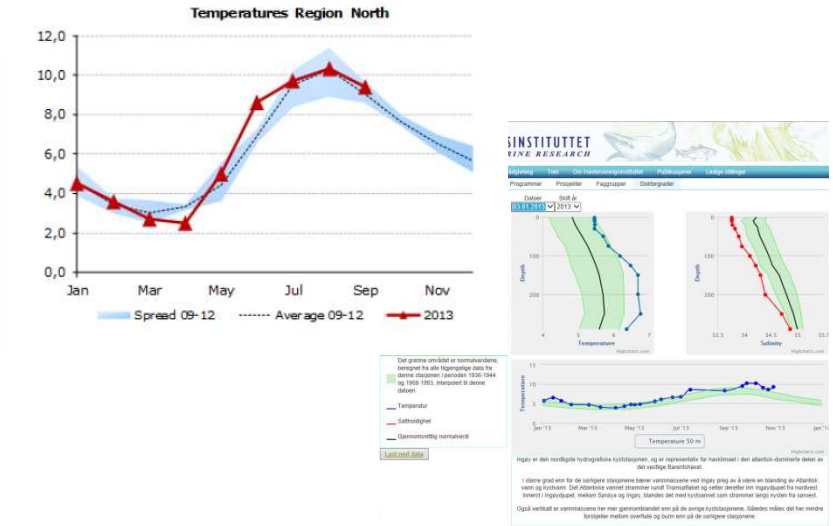
Source: Skretting / NRS / SalMar

Ocean thermocline (depth vs. temperature)



Temperatur

	Hordaland	Dybde (m)				Døgn
	As-Is	20	50	75	To-Be	As-Is
January	5,5	5,5	6,0	8,0	8,0	165
February	4,0	5,0	6,0	8,0	8,0	120
March	5,5	5,5	6,0	7,0	7,0	165
April	6,0	6,0	6,0	7,0	7,0	180
May	9,0	8,0	6,0	7,0	9,0	270
June	10,5	10,0	7,0	7,0	10,5	315
July	14,0	10,0	8,0	7,0	14,0	420
August	15,0	16,0	10,0	9,0	16,0	450
September	14,0	16,0	13,0	10,0	16,0	420
October	11,0	13,0	12,0	11,0	13,0	330

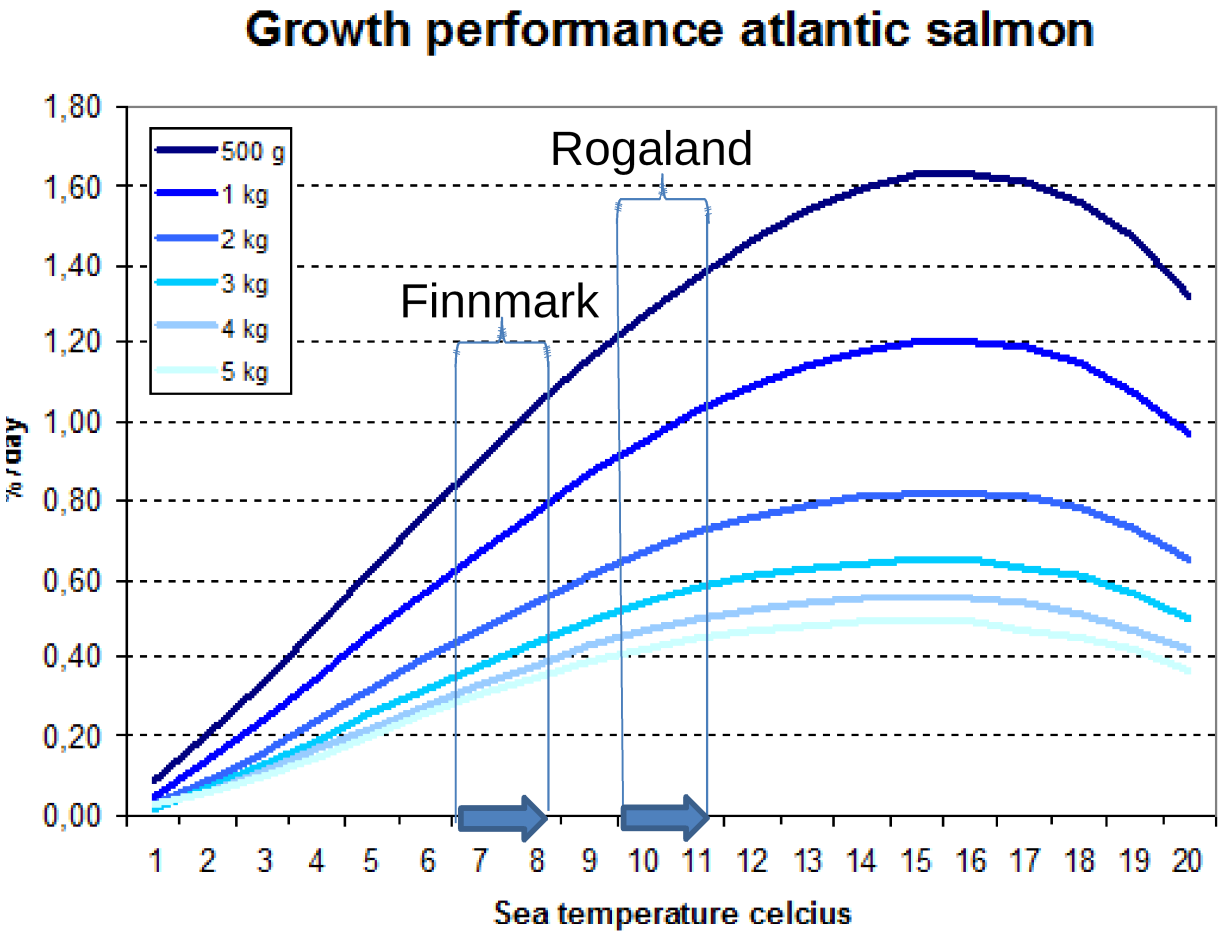


Temperatur

	Finnmark	Dybde (m)				Døgn
	As-Is	20	50	75	To-Be	As-Is
January	5,0	5,5	6,5	6,0	6,5	15
February	4,5	5,0	5,0	4,5	5,0	13
March	3,0	4,5	4,5	4,5	4,5	9
April	3,0	5,0	5,0	4,5	5,0	9
May	4,0	5,0	6,5	6,0	6,5	12
June	7,0	7,0	8,5	6,5	8,5	21
July	9,0	9,0	9,0	8,5	9,0	27
August	10,0	10,5	10,0	9,0	10,5	30
September	9,0	10,0	10,0	10,0	10,0	27
October	7,5	10,0	9,5	10,0	10,0	22

Source: NRS / Havforskningsinstituttet / Akvatech

The ability to better control the temperature…

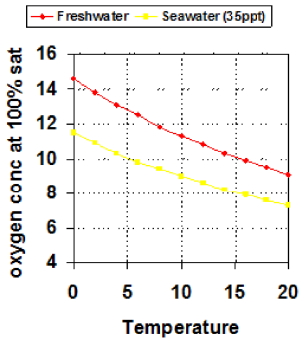


- Possible increase of yearly average temperature in the range of 15-25%
- Highest impact when the upper water layer is cold

Source: Skretting / Akvatech

Oxygen

Oksygenbehov hos fisk



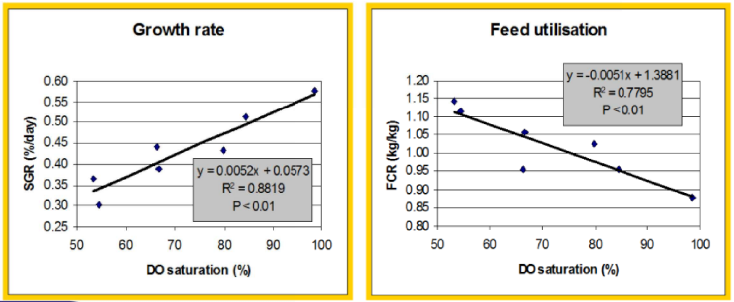
- Fiskens oksygenbehov øker med økende temperutur
- Tilgjengelig oksygen avtar økende temperutur
  - Sjøvann inneholder 20% mindre oksygen enn ferskvann

EWOS Innovation

Resultater fra forsøk

Effekt av redusert oksygen på vekstrate og fôrfaktor
Laks i sjøvann, 8-9 °C 24 april – 17 juni 2002. EWOS Innovation, Dirdal

Effekten på vekstrate (SGR) er mer markert enn på fôrfaktor (FCR). 45% reduksjon i vekst, 30% økning i fôrfaktor ved å redusere oksygen til 50% metning.



EWOS Innovation

.. Ved kontrollerte studier i innendørs kar hos EWOS Dirdal undersøkte prosjektet langtidseffekten av redusert oksygen på stor laks. Det viste seg at ved selv lav temperatur (8 – 9 °C) medførte moderat oksygensvikt på 70 – 85% av metnings nivå nedsatt vekst og fôrutnyttelse.

… Kontrollert tilsetning av oksygen i laksemærer ved EWOS Oltesvik sommeren – høsten 2003 indikerte positiv effekt: selv ved relativt kjølig vann i august – september (< 17 °C) og moderat oksygensvikt medførte oksygentilsetningen ca. 10 % økt sluttvekt, noe bedre fôrutnyttelse og lavere dødelighet.

… Normalt forbruker fisken i mæra 10 – 30 % av oksygen som tilføres med vannet utenfra. Da er det stor risiko for at det oppstår vekstbegrensende svikt.

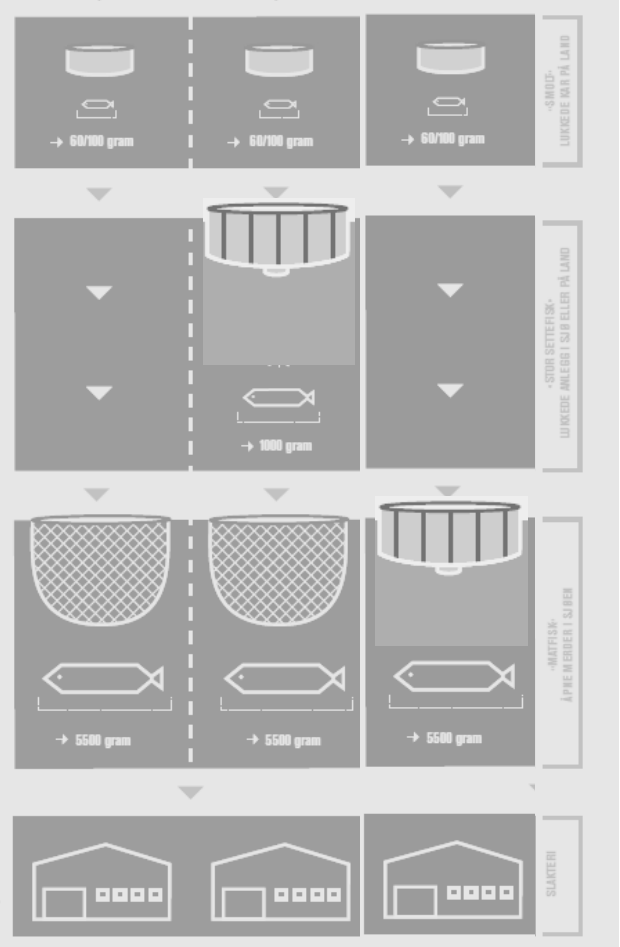
Kilde: EWOS / Akvatech

By increasing the dissolved oxygen saturation level from 60% to 90%, the daily fish growth increased from 0,37% to 0,52% and, at the same time, the FCR dropped from 1,08 to 0,93

Production models

Model I – as of today
Model II - partly closed
Model III - provides the following:

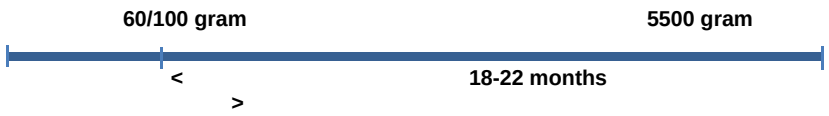
- Separation of farmed fish from wild fish
- Better control over rearing environment
- No solid waste pollution to sea beds
- Barrier against escapes, no predation
- Reduced disease transmission – no sea lice infestation or plankton blooms
- Reduced mortalities
- No feed waste or loss to drift, settleable solids removed
- Improved flesh quality



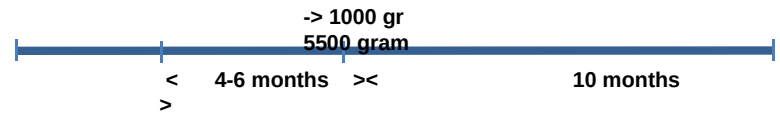
Experience

Production time

-> Model I

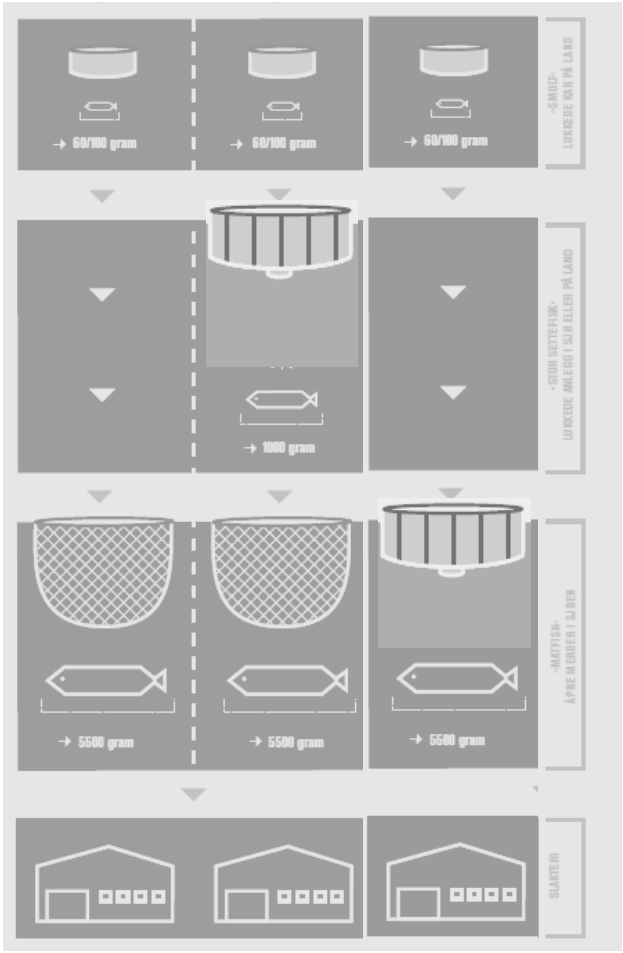


-> Model II



-> Model III

Mortality	**20-25%**	**5-7%**	
Feed conversion ratio (FCR)	**1,3-1,4**		**1,0-1,1**
Prod. time	**18-22**	**13-16**	



I **II** **III**

Source: PAI / Akvatech

Experience

Production cost

-> Model I

60/100 gram — 5500 gr

9 kr — 130 kr +

-> Model II

-> 1000 gr

5500 gr

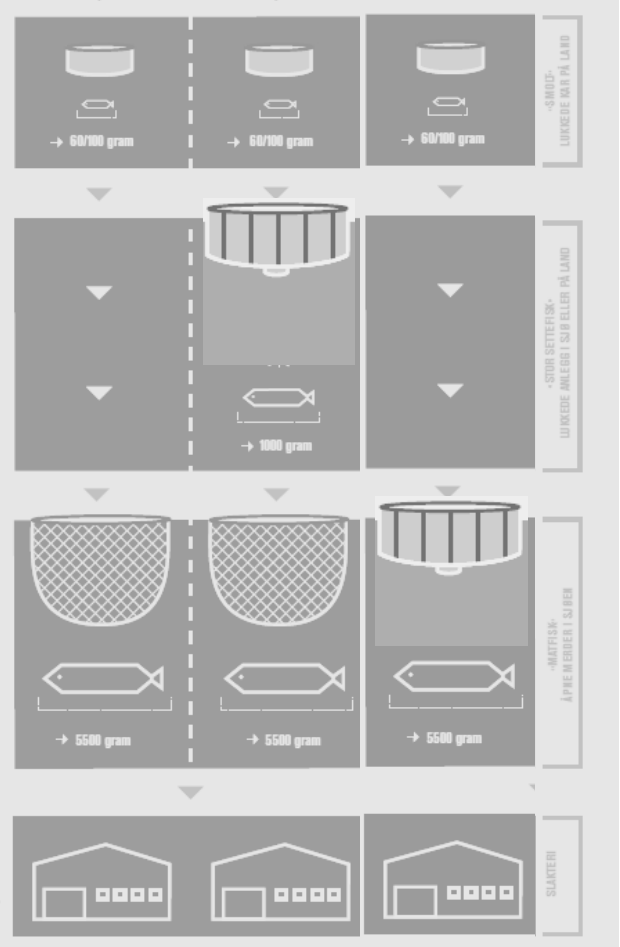
22-24 kr — 115 kr +

-> Model III

5500 gr

100 kr +

Mortality	**20-25%**	**5-7%**	
Feed conversion ratio (FCR)	**1,3-1,4**		**1,0-1,1**
Prod. time	**18-22**	**13-16**	



I II III

Source: PAI /Akvatech

Empirical data (1/2)

Feed conversion ratio (FCR)

Mortality

Source: AgriMarine Holdings Inc.

Empirical data (2/2)

Water exchange rate	Minimum 30 minutes, at normal operations 45 minutes
Fish density	Close to 75 kg/m3
Fish growth	Measured increase up to 35% compared to commonly available empirical data
Operational costs • Pumping system • Oxygen	0,10 – 0,15 KWh/kg 0,20 – 0,30 KWh/kg

Source: AgriMarine Holdings Inc.

Experience

- Reduced probability of fish escapes
- Improved fish health
- No treatment of sea lice needed
- Reduced mortality
- Reduced Feed Convertion Ratio (FCR)
- Increased growth rate
- Oxygen and pumping costs combined are less that 1% of production costs

Reduced production costs and increased production effectiveness compared to existing commercially available solutions

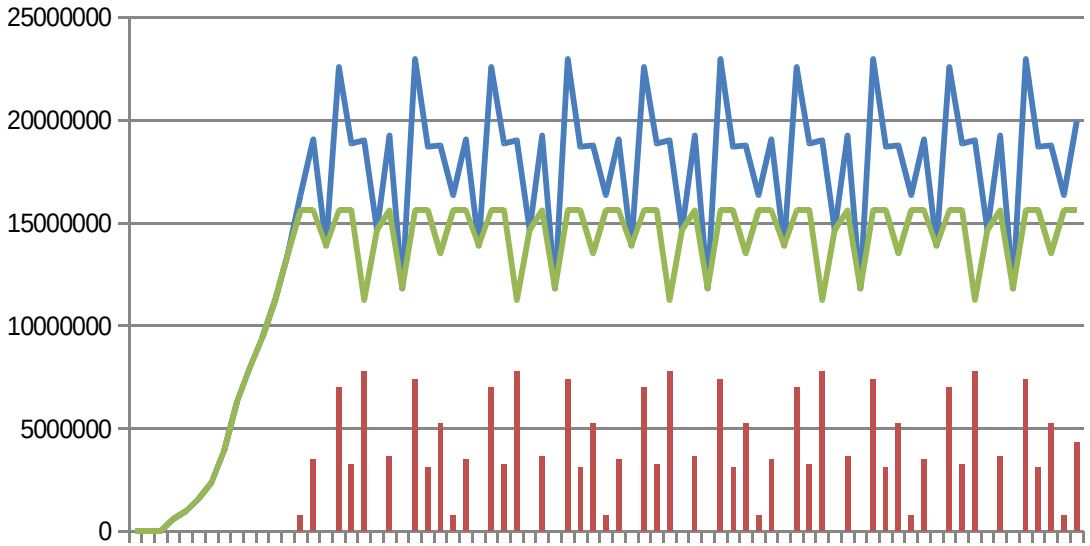
Source: AgriMarine Holdings Inc./Akvatech

Financial benefits

A reduction in production cost of 2-6 NOK per kg dependent on chosen method (II or III) of production

Facilitates a sustainable path for growth

Figures shows a changed production model based upon 20 concessions, each 780 MT. Production can grow from todays approx. 20 000 tons GWT, towards approx. 34 000 tons GWT



Source: Akvatech

Technology

Transformational technology - a game changer!

The technology addresses the current unsolved challenges in the aquaculture industry

The technology challenges and replaces today's solution

AquaDome

Eco Fish Aqua Farms AS (“EFAS”) har utviklet AquaDome – teksten under er hentet fra EFAS sider på Facebook.

> «EFAF AS LeitheGruppen Norges første sertifiserte lukkede oppdrettsanlegg for bruk i sjøen NS 9415 Oppdrett i lukket miljø testes nå med 5000 fisk satt ut 23 mars 2011
>
> Teknologibedriften EFAF (Eco Fish Aqua Farms) har utviklet det lukkede oppdrettssystemet AquaDome. Prototypen testes nå ut av EWOS Innovation, som bruker anlegget i sine fôringsforsøk. 5000 fisk ble satt ut i mars i år, og er slakteklare i januar 2012.
>
> AquaDome® er et lukket oppdrettssystem formet som en halvkule. Prototypen er utviklet med en diameter på 10 mete Prototypen testes nå ut av EWOS Innovation, som bruker anlegget i sine fôringsforsøk. 5000 fisk ble satt ut i mars i år, og er slakteklare i januar 2012.
>
> AquaDome® er et lukket oppdrettssystem formet som en halvkule. Prototypen er utviklet med en diameter på 10 meter...»

Pilotprosjektet er basrt på en tank på i overkant av 250 kubikk meter.
Fiskene som ble satt ut var 400 gr, og oppnådde slakevekt var planlagt etter 9-10 måneder. Utslakting var planlagt med en tetthet på 70 til 80 kg/m3 i mars 2012.

Det foreligger ingen offentlige resultater, utenom informasjon som er tilgjengelig på Facebook (både tekst og bilder).

Source: Selskapets egen informasjon Facebook 2012,2013

PreLine

PreLine Fishfarming Systems AS (www.preline.no) designer, utvikler, produserer og leverer ny teknologi for opppdrett.

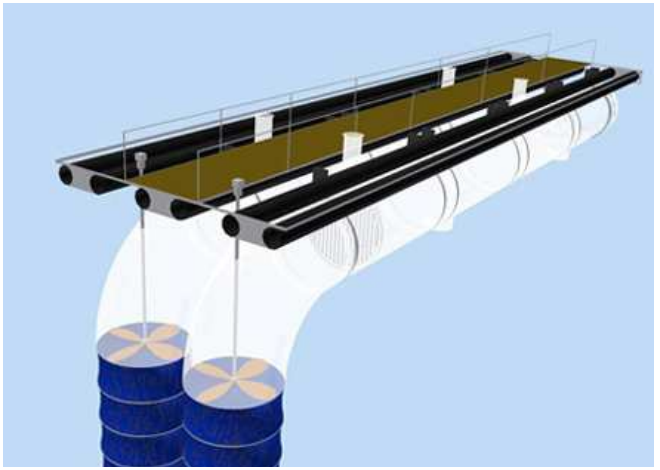
Selskapet har hatt to pilotprosjekter. Ett hos Lingalaks AS i Hardangerfjorden (bildet til høyre). Det ble produsert matfisk opp til 5,5 kg på 15 måneder.

Efaring fra pilotprosjektene er (hentet fra selskapets hjemmesider):

- The research result gave the following indications:
- Higher quality products / increased sale prices.
- No Lice
- Reduced feed cost.
- Higher growth rate.
- More muscle, reduced fat rate
- Reduced mortality
- Increased capital turnover

The system is therefore distinguished as better than a conventional fish farm both **biological and environmentally, technological and economical**

Selskapet har inngått en avtale med Lerøy Vest AS om bygging av et fullskala pilotanlegg for Post Smolt produskjon («extended smolt»). Anlegget kan med fremtidige tilpasninger og oppskalering benyttes til matfiskproduksjon. Planlagt størrelse er 2 000 kubikk meter.

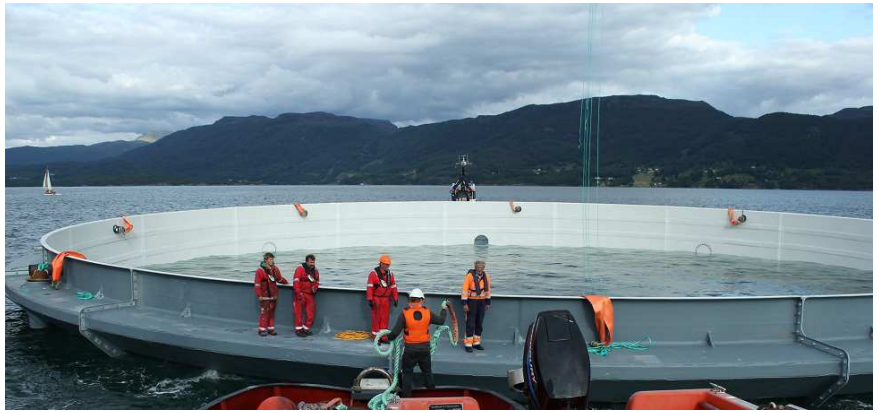


Source: Selskapets egen informasjon 2012,2013

Aqua Farm Equipment

Aqua Farm Equipment AS (www.aquafarm.no) har designet en lukket tank for oppdrett. Tanken er designet for lokasjoner med lav energi (bølgehøyde, tidevann, strømninger og vind), og vil bli produsert i glassfiber forsterket polyester (***GRP***, Glass-fiber Reinforced Polyester). Selskapet har invitert AGA for utvikling av løsninger tilførsel og overvåkning av oksygen.

Selskapet har ikke hatt tidligere pilotprojekter, men har inngått avtale med Marine Harvest Norway AS for uttesting av tanken. Tanken vil være på i overkant av 20 000 kubikk meter.



The report made for Aqua Farm Equipment AS had three main areas to focus on:

- Lice, Algae and Jellyfish
- Water Flow, Oxygen and Temperature
- Water Circulation and Current
- The conclusions the 4 researchers ha positive with regards to a closed cag long as some criteria are fulfilled. Re it:

Source: Selskapets egen informasjon 2012, 2013

AkvaDesign

AkvaDesign AS (www.akvadesign.com)

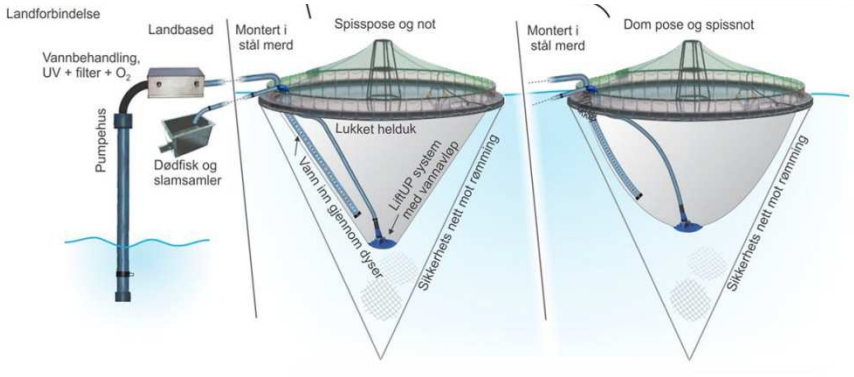
Ny lukket merdteknologi - rettigheter sikret gjennom patenter, design og varemerker
I to år har AkvaDesign jobbet med ny teknologi for lukket anlegg ved Havbrukssenteret på Toft i Brønnøysund. Nå foreligger ny teknologi som er dokumentert og har vist svært positive resultater. Cand. Scient Anders Næss har 20 års erfaring fra teknologiutvikling i havbruksnæringen. Næss står bak prosjektet i samarbeid med Fjord Marin. - Jeg har lenge hatt stor tro på at lukket anlegg er fremtiden for havbruksnæringen, men det er godt å få det testet ut og dokumentert, sier gründer Anders Næss.
AkvaDesign AS har sikret rettigheter til den nye teknologien gjennom flere patenter, design og varemerker.

Source: Selskapets egen informasjon 2012, 2013

Botngaard

Botngaard AS (www.botngaard.no)

Lukket merd i sjø er et internasjonalt KMB prosjekt med deltakere både fra Norge og USA. Løsningen gir et anlegg med dobbel sikring ved bruk av både not og duk. Det er en energieffektiv løsning som kan forkorte settefisk-fasen i åpen sjø med 8-10 måneder.
Løsningen kan også vise seg å gi miljøfordelene som forventes av landbaserte anlegg med langt lavere energibehov, uten inngripen i terrenget og til en brøkdel av prisen.
Lukket merd er beregnet for å forlenge settefiskfasen til 800 gram, noe som gir en langt mer robust fisk og er tenkt som en ventemerd for stamfisk. Det pumpes inn vann fra 20-30 meteres dyp og merden kan påkobles slam behandling slik at den kan legges til skjermede lokaliteter.
Prosjektet har støtte fra Norges Forskningsråd. Deltakere i prosjektet er Botngaard, Aqualine, ITT Flygt, LiftUp, Smøla Klekkeri & Settefisk, NOFIMA, Patogen Analyse, New Hampshire University, USA og Freshwater Institute, USA.



Source: Selskapets egen informasjon 2013, 2014

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