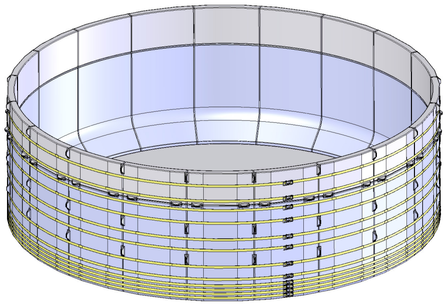
Part (A) Final Publishable Summary Report



This report covers the work carried out in during the life of the OptiTEMPtank project. More detailed reports are found in the appendices on specific deliverable documents.

The overall industrial objective of the project is to develop a modularly constructed, thermally insulated, low running cost plastic aquaculture tank. The OptiTEMPtank system will be constructed from rotationally moulded plastic segments with internal foaming to provide thermal insulation to prevent heat loss, these panels will be integrated to provide a water-tight seal and include the development of a control system for monitoring the tank, which would contribute towards the integrity of the system. The OptiTEMPtank system will be fitted with a closed loop temperature control system will monitor the tank water temperature and control incoming water temperature to maintain the optimum environment to promote maximum growth. A further innovation is represented by the cost effective and ecologically sustainable exploitation of the biogas generated from the fish themselves (aquaculture faeces and unused food waste) to heat or cool the water. This will be achieved through the use of an innovative micro-scale anaerobic digestion biogas generator. Even the waste sludge from the biogas generator will be utilised within the local farming communities as nitrogen and phosphorus rich fertiliser. However, to realise our goal new technology is required to be developed in the areas of micro-scale biogas systems and rotational moulding.

The technical work period (1st December 2008 – 28th February 2011) has been spread over the tasks in the following Work Packages:-

- WP1 - Enhancement of Scientific Knowledge
- WP 2 - Development of Insulated Tank
- WP 3 - Development of Biogas Generator and Heating/Cooling Systems
- WP 4 - System Integration, Testing and Industrial Validation

The OptiTEMPtank 'Kick-off' meeting was successfully held at SPI Play Europe Limited, UK on Tuesday 11th November 2008 where partners attended and expressed much enthusiasm, agreeing that the initial concept model development should start from month 1. This also included a site tour of Selonda's fish farm on Monday 10th November, where the fish farming operation of Sea Bass was explained. This site still being developed and producing excellent production rates of around 9 months to market for their Sea Bass at approximately 500gs. The key learning points were:

- The use of recirculation technology where the sea water is sterilised and detoxify producing 'blue water'.
- A constant temperature which was controlled by the thermal insulated buildings. The fish and equipment generate heat – maintain 24℃ for optimum growth. Thus low operating costs.
- Removal of all that the fish put into the water.
- Add to the water all that the fish take out of the water.

The requirements for specific species such as Salmon, Trout, Sea Bass, Sea Bream etc. was defined, such as the microbial conditions in the aquatic environment and water flow analysis in tanks.

Also the various constructs used for Aquaculture tanks for in-land based fish farming were reviewed such as: Concrete, Concreted coated with 2-component paint, Concrete with polyethylene lining, Glass fibre, Steel, Steel lined with rubber, PVC cloth or polyethylene, Aluminum lined with PVC cloth or glass fiber plates, Polyethylene/Polypropylene, Concrete tanks delivered in sections or molded in one piece and many more.

In many countries, concrete is the cheapest option but inferior build can lead to water leaching into the concrete, expansion of reinforcing rods and tank cracking. In the last years many concrete tanks have been installed with 4 mm HDPE lining. This has resulted in increased interest for HDPE as farmers have documented a reduction in mortality since using the HDPE lining. Concrete tanks with HDPE plates moulded in exist on the market, good product but the pricing is much higher than that foreseen for the OptiTempTank solution.

The below table shows standard tank dimensions for salmon

Tank Type	Diameter, meters	Height, meters
Initial feeding	6 - 7	1.5 - 2
On growing	8 - 12	2.5 - 4
Final feed, prior to net cage placement	14 - 16	3 - 4

It was agreed at the 3 month meeting that to ‘demonstrate proof of principle’ of a roto-moulded tank design the consortium would have to build a full size pilot system of Ø12m x 4m high tank, which a specification was drafted for.

Material performance requirements were determined through detailed discussions with consortium members. Candidate materials were reviewed and selected, initially, the decision was made to retain two materials as potential candidates for manufacturing the tank wall components. After finite element analysis was performed on components composed of both types of material. It was found that the difference in performance was small. The decision was therefore made to use DOWLEX NG2432UE as the material for the construction of the tank wall components due to its significantly lower cost. Following the evaluation of a variety of potential filler materials, two candidates have been chosen for further consideration. These are Rigid Polyurethane Foam and Expanded Polystyrene (EPS).

In order to create a watertight seal between tank wall components, a variety of potential sealing solutions were considered. Each of the sealing methods listed were discussed in detail at the project three month meeting. During the discussion, it was decided that the preferred method of sealing the tank components together would be to use a welding process.

The development of a method of locking the panel components together was extensively reviewed. The decision had been made to incorporate external strengtheners into the design of the prototype tank. These would act to encircle the outside of the tank and secure the wall components in place. As displacement of the tank wall components would be prevented, the welds used to seal the components together are not envisaged to experience significant stresses and are unlikely to rupture. There is therefore no need for interlocking features to secure components together within a wall. As a result, no interlocking features were designed for the sides of the tank wall components, as it is assumed that the external strengtheners will prevent the components from separating. However, the sides of the components have been designed to optimize contact and assist the welding process. An interlocking feature has been designed for the interface between the lower and upper tank wall components. This is to assist with locating the components during assembly, as well as to help prevent separation of the components due to hydrostatic pressure.

Following the development of a target specification, a variety of concept designs were considered. At the same time the stress state that the tank would experience during use was analysed. The tank design was then refined following the selection of an external strengthener and type of filler. Finally, details were added to assist the rotational moulding process following discussions with a toolmaker. The finished design of the lower wall component is at a height of 3m with an external sector angle of 18°. This is equivalent to approximately 1.9m at its widest point. It is designed with a wall thickness of 10mm which corresponds to approximately $0.15m^3$ of solid polymer material required to make the moulding and an unfilled weight of 142kg when manufactured from pure DOWLEX NG2432. The design of the upper tank wall component required less consideration than the lower wall component. This is because the stresses that the component is expected to experience during use will be much lower. The top wall component has been designed to interface with the final version of lower wall component whilst allowing the manufacture of 4m high tanks.

Two toolmakers, both capable of producing tooling of the required size, were approached and asked to quote for the tank section tooling. Sheet steel tooling was chosen for the prototype tank sections, as it would minimize the tooling weight (facilitating the rotation-moulding process). In addition the steel tooling is cheaper than an aluminium version and can more easily be modified if needed. The first tool to be manufactured was the base section tool. The tool was then shipped to the moulding facility for pre-moulding tests. At the time of writing these trials are currently being performed.

Research has been carried out to gain a greater understanding of methane generation from the fish waste. The waste products from land based fish farms consist of fish faeces, uneaten feed and dead fish, of which faeces is the major part. Further, evaluation of overall energy consumption and demand in land based fish farms are investigated in order to evaluate the potential of biogas from waste as a source for energy supply including how biogas can be used to fuel systems to heat or cool water in fish farm tanks. Further work is required on optimizing the approach to biodigestion before firm conclusions can be made as to the viability of methane / energy production as a tool towards promoting sustainability of aquaculture and this activity is focused in the next reporting period.

Further work included basic anaerobic tests to be carried out on the fish solids sludge samples to determine gas output and biomass input required. Project partners Salten Havbruk AS and Selonda UK are to be used as case studies.

The Bottom and top section mould tools that were manufactured were dimensionally checked successfully where a 3% shrinkage tolerance was used. Due to the large size of the bottom rotomoulded section a cooling rig was required to prevent the part from deforming during the cooling process. When the part is cool enough to handle and removed from the tool it is placed in the cooling rig which holds the shape of the part as it is pressurised with air during it's final cooling stage. 1st prototype samples have been produced from both tools and minor modifications carried out.

The OptiTEMPtank 'mid-term meeting' meeting was successfully held at Haywood Rotomoulding on Wednesday 16th December 2009 which included a site tour. At this meeting the 1st prototype samples of the bottom and top rotomoulded tank sections and tools were reviewed and analysis of the filler material discussed.

As determined in period one of the project a filler material was required in the bottom tank section for structural support, but also would provide thermal functionality. Expanded polystyrene foam (EPS) was suggested as a filler to be used, it is a structure obtained through filling a component with polystyrene beads and injecting steam. The use of EPS has several potential advantages, Low weight, Excellent Insulation properties and Lower cost. MatRI carried out FEA Analysis on the EPS material using the material properties determined in the earlier tests and stresses experienced by tank wall were acceptable. Based on the results of the simulation, EPS would be suitable as filler. A 'filling jig' for the bottom take section was required; this was to hold the section shape during the high temperature and pressures experience during the filling.

Further prototyping trials and modifications to the tool design were carried out before 22 (twenty two) prototypes of bottom tank sections were ready for the pilot build. The sections where shipped in May 2010 from Haywood to Plastsveis AS, Somne, Norway. Following, a further 22 (twenty two) prototypes of top tank sections where produced and shipped.

At the 18 month meeting at Plastsveis AS, Somne, Norway which included a site tour where the consortium was able to see the Plastsveis facilities. The ground base and floor was prepared, laid and prototype bottom tank sections successfully assembled in place.

An evaluation of information provided in WorkPackage 1 has been performed and more especially task 1.4 "Enhancement of understanding of methane generation from fish farm waste biomass" as well as performed a case study focusing on Selonda UK and biogas potential from their "waste" including evaluation of biogas as source for their energy requirements. As identified in WP1, when fish are held and fed in aquaculture systems there is a considerable production of organic waste. It is crucial for a fish farmer to reduce the amount of waste because waste and once removed from the water of an aquaculture plant (flow through or recirculation), solid waste represents beyond doubt a resource that should be utilized. Selonda UK is a state of the art landbased aquaculture plant with recirculation technology for production of sea bass. The case study performed at Selonda UK show that the biogas (methane) energy potential at Selonda UK represents approximately 8 % of their total energy consumption annually (conservative estimate).

Based on the case study, further analyses of biogas potential are performed. The bio methane potential (BMP) is used to estimate the amount of methane that could be produced from anaerobically digesting material at 35ºC. Tests to assess the potential for implementing anaerobic digestion to treat both the sludge and waste liquor generated from fish farming facilities have been carried out. The test of the bio methane potential (BMP) demonstrate that the EFC sludge is comparable to sewage sludge and so if sufficient quantities are generated it may be viable to implement an anaerobic digestion facility. The EDF liquid does not contain sufficient COD to be worth treating this by anaerobic digestion; however it could be used to dilute the sludge if the solids concentration was too high and this may contribute some additional biogas. The input data was analysed and assumptions made, output data produced which defined the design of four reactor scenarios. The COD and VS contents are too low for the application of an anaerobic 'continuously-stirred' reactor with typical 20-30 days hydraulic retention and too low for the classical up-flow sludge blanket reactor. Consequently three of the samples (Scenarios A, C and D) are more suitable to treatment through a hybrid sludge blanket-Anaerobic filter type anaerobic reactor, particularly with the need for dilution with fresh water to prevent sodium and potential inhibition. In the case of the Sample of sludge from the main effluent tank (scenario B), the high COD would require a fairly large filter bed. This would make the reactor tank impractical for the intended application.

A control system for the monitoring and surveillance of the tank integrity was developed. The control system does included tank deformation control, system supervision and control, measuring and logging deformation data and remote video and system surveillance. PLC system is designed to log tension data continuously to the PLC flash memory. Beside the log functions PLC has also monitoring, alarm, historical trending and setup functions.

Teknologisk Institutt AS has established a comprehensive testing and monitoring program programme including the use of tensions cells, dial gauges, measuring bracket for seams and temperature sensors. The automatic logging system is the measurement and logging of temperature and tension cells. The data is processed by a PLC and the results are displayed on a webpage.

The test tank was mounted and installed during the summer of 2010 by PLAST-sveis AS at their site in Brønnøysund, Norway. The tank was 12m in diameter, 2.9m high. 20 elements were welded together and to the bottom canvas. Compressed sand made the base of the construction. Straps were tightened around the tank. They were supposed to withstand the pressure from the water when the tank was filled. Several different measuring devices were installed and full scale tank testing was conducted in Brønnøysund, Norway. The goals for this test was to see of the tank would withstand the water pressure, reveal existing and/or new cracks/leakages and measure different properties of the tank construction before, during and after filling. Initial leaks were observed during the tests and further welding was performed. The following parameters were planned measured when the tank was empty, full and during filling: element deformation, element shape, gap changes, strap tension, tank shape, and elongation of straps.

Due to severe weather conditions since the end of 2010 for several months delayed the progress of the validation trials and it was agreed with the co-operation of the partners these will be completed post project so a greater knowledge can be gained before the system can be commercially optimised.

Beneficiary Number	Beneficiary Name	Beneficiary Short Name	Country	Date Entered Project	Date Exit Project
1 (Coord)	SPI Play Europe Limited	SPI	UK	Month 1	Month 27
2	GRYF HB, spol. s r. o	GRYF	Czech Republic	Month 1	Month 27
3	Talbot & Talbot (pty) Ltd	Talbot	South Africa	Month 1	Month 27
4	Plastsveis A/S	Plastsveis	Norway	Month 1	Month 27
5	Tobermory Fish Company Ltd	Tobermory	UK	Month 1	Month 8
6	Salten Havbruk A/S	Salten	Norway	Month 1	Month 27
7	Resinex S.A.	Resinex	Luxembourg	Month 1	Month 27
8	Selonda UK	Selonda	UK	Month 1	Month 27
11	Haywood Rotomoulding Ltd	HRM	UK	Month 8	Month 27
9	**The National Institute of Technology**	TI	Norway	Month 1	Month 27
10	The UK materials Research Institute	MatRI	UK	Month 1	Month 27

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