Biodiesel in cold climates
Final report

December 2015

Team

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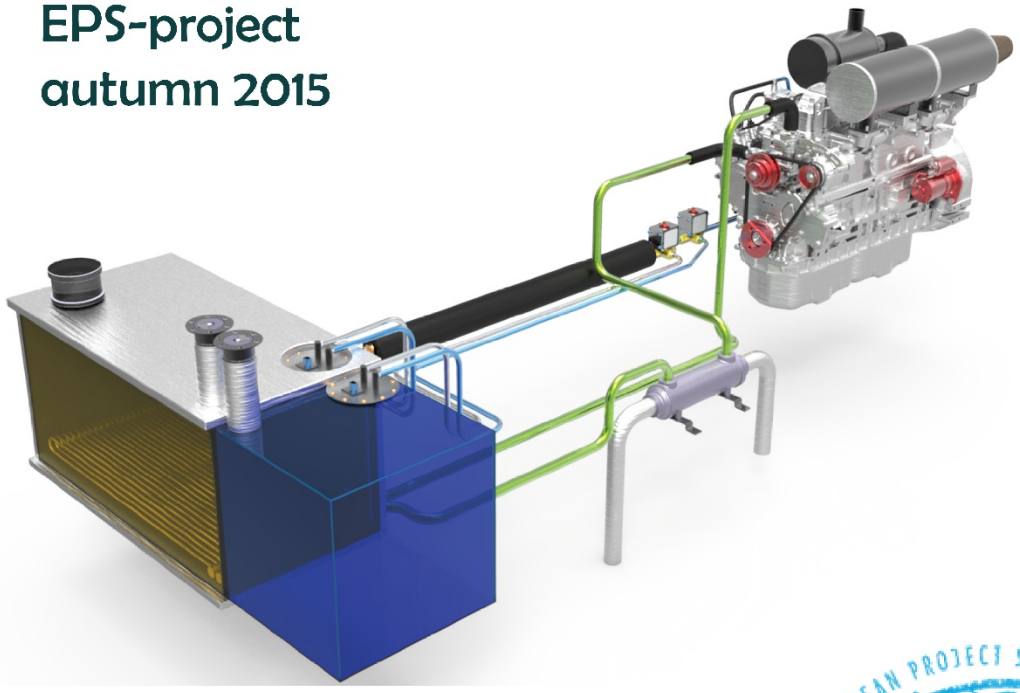
autumn 2015



FIBIOD

NOVIA
UNIVERSITY OF APPLIED SCIENCES

EUROPEAN PROJECT SEMESTER

PREFACE

This report is a final work as fulfilment of the European Project Semester at Novia University of Applied Sciences in Vaasa during the autumn semester in 2015 titled "Biodiesel in cold climates". This report focuses on what issues will arise when using biodiesel in cold climates, what individual solutions can be found for these issues and how these solutions can be implemented in a full concept system. This report is based on primary and secondary data received from various online and offline sources.

The secondary objective behind this project is to get knowledge of different fields of studies and gain experience in cross-cultural communication and teamwork. All members of the project team are satisfied about how the communication and project process took place and continued to improve along the way to this final report. As individuals and as a team we would like to thank our coach Niklas Frände for helping to guide this project in the right direction and we would also like to say thank you to Mikael Ehrs and Royer Nylund for providing useful feedback during this period.

Each team member has taken valuable lectures on environmental awareness or industrial sales management, cross cultural communication and English with the main purpose of increasing the level of this report.

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1. INTRODUCTION

The European Project Semester is a program, which promotes collaboration between students from all around the world. We are a team of five students from different countries and a different scholar background working together at Novia University of Applied Sciences in Vaasa, Finland. Our goal is simple, work on a project together and use our different skills to produce something better than expected and improve our personal English skills and our cultural knowledge about other countries.

1.1. EPS

The European Project Semester is offered by 16 European universities in 12 different countries around Europe. This program is focused primarily on engineering students who have achieved two years of their study but students from other disciplines are also welcome to join.

The EPS goal is to prepare students for today's challenges by using actual subjects for each project. The students have to work in little groups supervised by a coach. They also have related courses to help them during the semester such as cultural differences, team building, project management and technical English.

Students should learn how to work as a member of a team in English, which improves their expression skills. It is a great experience for them to leave their comfort zone and discover new cultures, people and forge their personal behavior.

1.2.PROJECT GROUP

1.2.1. THE TEAM

Astrid BIENSTMAN
Belgium

University :
Universiteit Antwerpen

Field of studies :
Product Development

Jennika HANNULA
Finland

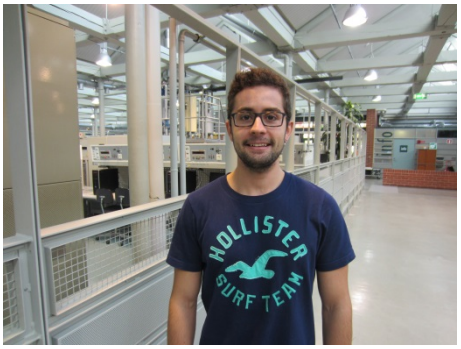
University :
Novia University of Applied Sciences

Field of studies :
Industrial management and engineering

Nicolas FERNANDEZ LUNA
Spain

University :
Universidad Rey Juan Carlos

Field of studies :
Energy Engineering



Mik LAMMERS
The Netherlands

University :
Avans University of Applied Sciences

Field of studies :
Mechanical Engineering

Raphaël Zéèv DUPATY
France

University :
Ecole Nationale d'Ingénieurs de Tarbes (ENIT)

Field of studies :
Mechanical Engineering

1.2.2. CODES OF CONDUCT

Working together in a team can create some problems. It's important both for the project process and for the motivation of the team members that these problems are handled correctly. The team needs rules so the members will know which behaviour is expected and what the consequences are if these rules are broken. The rules are written in the so called 'codes of conduct'.

Date: 30/09/2015

- **Communication and information**

Dropbox will be used as a platform for gathering information and saving files. Every team member is expected to check the general excel file for updates in order to keep up-to-date with the project. Google drive will be also used if each team member has to work in a document at the same time. The main communication tool will be a WhatsApp group. The majority of the meetings will be held in the EPS-room or in one of the group rooms in the Tritonia library.

- **Meetings**

There will be a weekly team meeting that is obligatory for all team members. Before every meeting an "Agenda" should be made by the chairman and sent out to all team members and the coach. Other meetings that are planned should be attended unless there is a good and acceptable reason for absence.

The meetings will be opened by the chairman. The Secretary will take notes and send out the minutes of meeting. These roles circulate every meeting.

- **Team Rules**

If the team members have different opinions about something you should turn this situation into a win-win situation. In case of disagreement, a discussion will be held in order to get all the team members behind the same idea.

- **Absence**

Team members are allowed to participate in the student trips at the condition that the expected work is done at the end and that this absence doesn't create any problems for the rest of the team. The team member will have to contact Roger and the coach about his or her absence. If any team member would like to arrange a personal trip, it should be discussed by the entire team and this member will make up for the time of absence by catching up on the lost hours.

If a team member is sick or cannot do the work, then he will contact the rest of the team to notify them about his or her absence.

- **Working norm**

Each member agreed to the quota of 30 work hours a week (15 for Jennika). The team members keep track of their own working hours in the excel file. The subject of the work done in these hours will be filled in the excel file by the team member. As Jennika has other lectures, she will have to meet with the team on Wednesday afternoon, Thursday morning and Friday.

- **Expression**

Each team member has to be comfortable with taking part in discussions. This means that all the team members should be aware of being too dominant in the conversations.

- **Writing**

All the information will be written down in a personal document. When the information is read and approved by the group it will be added to the report.

- **Responsibilities**

Two main roles in the team:

Project manager: Updates the information, keeps a look on the report, verifies the tasks list and delegates the work.

Secretary: Updates the planning (Gantt chart), checks if the accomplished work is in accordance to the goals set for this task, responsible for the chairman and secretary of the weekly meetings, reports to the project manager if there are any issues.

1.2.3. NAME, LOGO AND WEBSITE

Picking out a good name for the project wasn't an easy task. The name the entire team could agree on was *Fibiod.* This is an abbreviation for Finnish Biodiesel.

There were several elements that should be included in the logo in order to create an icon that represents the values and goals of the project. The fishermen and the sea are represented by the boat. The snowflake on the sail represents the cold weather conditions. To add something to represent the green and biological part of the project there were two options. The first one was a sail in the form of a leaf blowing in the wind, the second one was a sail in the form of a drop of biodiesel. Since the first one wasn't very clear as to what it was, the team chose the second logo.

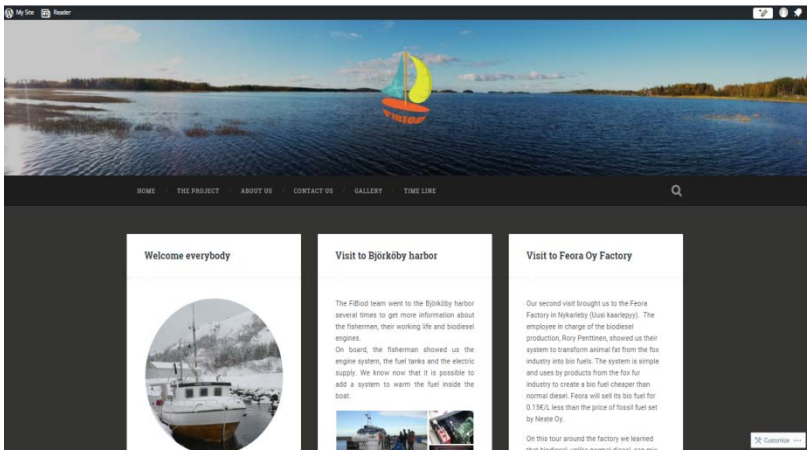


Illustration 1.- Main page of the website (Fibiod.wordpress.com)

The website is a key tool for the project, it has several functions such as represent the project and show the progress of the work. First it has to look well and easy to use that is why the WordPress tool has been used, furthermore it is really easy to handle. A 3D model of the developed system and the final report can be found in the webpage as well.

The Website is composed by six different sections:

- Home : This is the main page where all the articles are posted, also the most interesting section in order to find information about the progress of the work.
- The Project: Information about the project and the 3D model.
- About us : Here are more information about the EPS and the team members.
- Time line : A part dedicated to the time line which shows all the different steps of the project.
- Gallery : In this section are our photos made during excursions and working sessions.
- Contact us : In order to contact the team for any reason, this section is the good one. It contains a form to contact us and a map which shows our position.

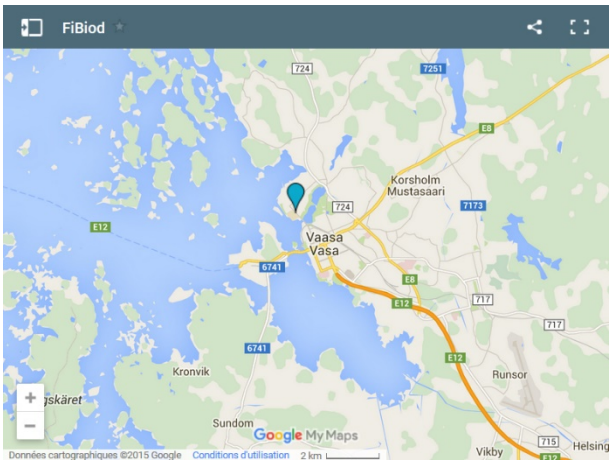


Illustration 2.-Fibiod map (googlemaps.com)

The footer is also full of information, it is composed with a schedule a list of all the older posts and a search tool if you want to find something special.

The website is located at this address: https://fibiod.wordpress.com/

Just have a look !

1.3.THE PROJECT

During the courses of Project Management there were several tasks concerning the project. The results will be summarized in this chapter.

1.3.1. MISSION AND VISION

- Mission statement

Develop a cheaper method in concern to the usage of diesel and biodiesel in winter in small fishing boats without losing energy efficiency.

- Vision statement

- Reduce the environmental impact compared to the conventional diesel.
- Find the best kind of biodiesel produced in Finland that can be used in small fishing boats
- Solve the problem of biodiesel freezing

1.3.2. PROJECT SPECIFICATION

The main goal is to understand the qualities and advantages of biodiesel and to analyse the needs of the boat owners. The results will be used to develop a concept of a modular system that will support the use of biodiesel in cold climates.

1.3.3. WORK BREAKDOWN STRUCTURE

The project will be divided into eleven steps. Not only will this make the project more controllable, it will also help to divide responsibility and tasks.

Project structure

1. Research about the topic
2. Set the boundaries according to the topic (scope)
3. Get some interviews, understanding of the needs.
4. Enumerate solutions
5. Define specifics of the solutions
6. Study the viability of solutions
7. Choose a solution
8. Concept the solution
9. Interviews in regard to the final solution
10. Final adjustments according to the interviews
11. Finalization of the project.

1.3.4. GANTT CHART

1. Research about the topic
2. Set the boundaries according to the topic (scope)
3. Get some interviews, understanding of the needs.
4. Ennumerate solutions
5. Define specifics of the solutions
6. Study the viability of solutions
7. Choose a solution
8. Concept the solution
9. Interviews in regard to the final solution
10. Final adjustments according to the interviews
11. Finalization of the project.

In order to keep track of the ongoing activities and time management, a Gantt chart was created. This chart helps the team to take notice of the time left for the current phase. Further on the team can look to this chart in order to prepare the next phases of the project. The most important goal of the chart is of course to keep track of the used time and the process. Small changes can be made since the chart is based rather on experience and expectations and not on facts.

1.3.5. RESPONSIBILITY

Each phase of the project has been assigned to a responsible team member. This doesn't mean that this student is the sole team member working on this step. Everybody has been assigned a step that fits his profile and experience.

	Jennika	Nico	Astrid	Raphaël	Mik	Comment
Task 1	S	S	R	S	S	Everybody has his/her own topic to research
Task 2	S	S	S	S	R	Boundaries have to be set by the entire team
Task 3	R	S	S	S	S	The interviews might be with Finnish/Swedish speakers
Task 4	S	R	S	S	S	
Task 5	S	S	S	R	S	
Task 6	S	S	R	S	S	
Task 7	S	S	S	S	R	
Task 8	S	R	S	S	S	
Task 9	R	S	S	S	S	The interviews might be with Finnish/Swedish speakers
Task 10	S	S	S	R	S	
Task 11	S	S	R	S	S	

1.3.6. BASIC ELEMENTS METHOD

This method was explained to the students in the project management courses and used to give an overall view of the project. This happens by listing all the tasks, people involved, resources and tools and the environment that the project will deal with.

1.3.7. RISK MANAGEMENT

There are several factors that need to be taken into account when working on this project. The risks mentioned here are the most important ones. Off course it will be necessarily to watch out for other risks that might occur.

Losing working hours
To finish the project successfully, it is estimated that all students will have to work 30 hours/week. In case one of the students leaves the project, either due health, motivational or other reasons, this quota cannot be met. The same goes for when a team member is demotivated and thereby not willing to fulfil the necessary working hours or deliver work of an acceptable quality.

Bad time management
The project is divided in several phases, the team has a limited amount of time to complete each phase. When one phase takes too long to be completed, all the other phases might have to be postponed as well. This might not only lead to an unfinished report but rushing might result in a decrease of the quality of the work.

Little response from fishing community
The target group for the project are fishermen. It is crucial for the concept to gather information in this community. Interviews with these craftsmen will result in a concept that fits the target group. Several problems might arise when trying to contact the community. First of all, they speak Swedish or Finnish. Finding fishermen that speak sufficient English might be hard in such a small community. Further on they might not want to take the time to talk with the team or answer the questions. Last but not least, finding fishermen that have experience with biodiesel. Fishermen aim to use the cheapest kind of oil, it is possible that they don't use biodiesel or even regular diesel.

Following the wrong tracks
In every project there is a possibility that the team takes wrong decisions. These decisions might result in an unfinished report, a bad concept and time loss. It is crucial to eliminate wrong options as soon as possible in the process in order to prevent these negative outcomes.

1.3.8. RISK MATRIX

The Risk Matrix, known also as Risk Impact/Probability Chart is used to help the team having an overall view of the risks, choosing which of them need special attention. The risk matrix is divided in two different dimensions: probability and impact.

Probability ↴		Impact				
		Insignificant	Minor	Moderate	Major	Severe
Very high	81-100%					
High	61-80%		Misunderstanding between teammates		Bad time management	
Medium	41-60%			Team-member gets ill	Technical problems / Losing motivation	Lack of individual involvement
Low	21-40%			Lose time because of a lack of knowledge	Little response from fishing community / Following wrong tracks	Missing deadlines / Solution doesn't match with the target group
Very Low	1-20%				Get stuck in a problem	team member quits project

Table 1.- Risk Matrix

1.3.9. PROJECT WORKFLOW

The courses in project management have helped the team to approach the tasks more organized. Furthermore, it taught the team to handle issues that appear in a project such as communication issues. These courses were really helpful and well realised by Roger Nylund. The research part was quite long and not easy but due to the excursions the team stayed motivated. With the Gant Chart made in the project management class, the team had something to follow with deadlines and targets. Sometimes it was hard for the team to work all together on the project with the other lectures and assignment, especially for Jennika who had to follow a semester with a lot of hours.

1.3.10 VALUE ANALYSIS

Value Analysis

Earned value analysis is done for the reason to keep track on the process in relation to the costs. This means that the money spent and the actual progress is compared with the projects time plan and budget. The Fibiod team made a Gantt-chart, that would give a general view over the projects timeline and a task list was made to give the project a general structure. The Gantt-chart and the project structure was introduced in chapter *1.3.3 Work breakdown structure* and chapter *1.3.4 Gantt chart.*

The following things that need to be calculated before a value analysis diagram can be made are the planned cost, actual cost and the earned value of the project. The following terms are explained by J.J. Heagney like this:

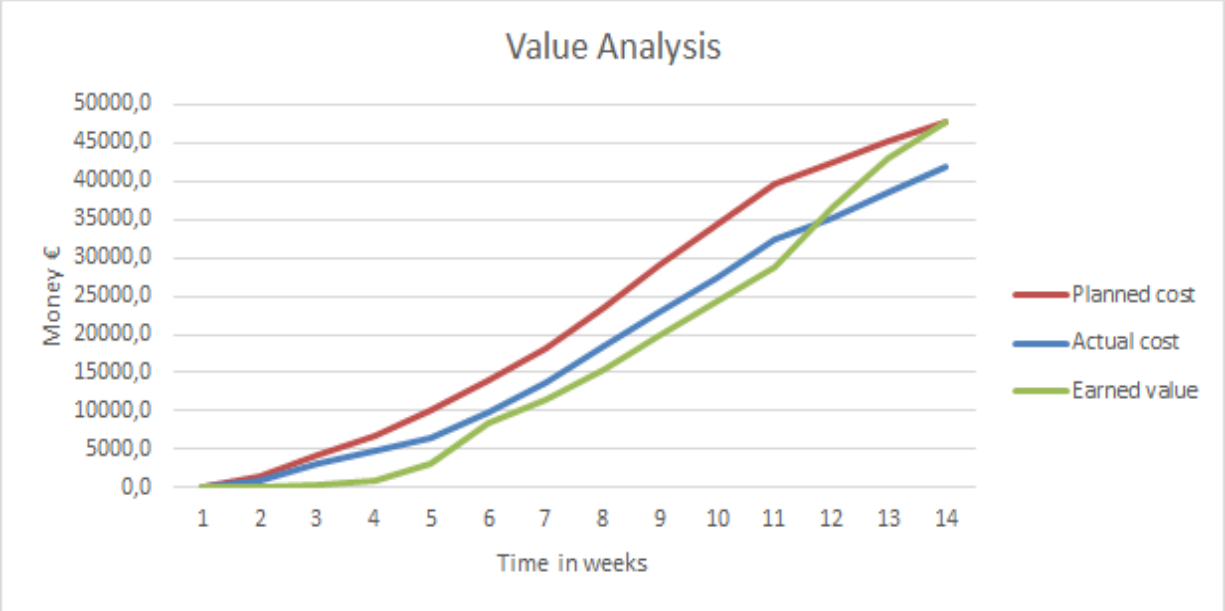
- Planned Cost can also be called budget cost of work scheduled (BCWS). In other words, it's the planned cost for each task for every week.
- Actual cost of work performed (ACWP) shows the amount of money that's used for completing a task at a given time period.
- Earned Value or budget cost of work performed (BCWP), means that the budgets cost of work that's actually preformed in a given period.

Before these three values can be calculated, we needed the total working hours from each member and the hourly wage. The total working hours can be found in the appendix. These calculations can be seen in the table 2 below. The planned hours are bigger than the actual hours because the actual tasks took less time than the budgeted one. The project budget was also higher due to the high planned hours but the actual cost was less.

Week	Planned hours	Actual hours	Task	Planned cost	Actual cost	Earned value %	Earned value
1,0	0,0	22,0	0	0,0	0,0	0,0	0,0
2,0	75,0	49,0	1	1500,0	980,0	3,0	45,5
3,0	135,0	102,5	1	4200,0	3030,0	6,1	254,5
4,0	135,0	83,0	1+2	6900,0	4690,0	13,6	940,9
5,0	135,0	73,0	2+3+4	10050,0	6393,3	31,8	3197,7
6,0	135,0	116,0	4+5+6+7	14100,0	9873,3	59,1	8331,8
7,0	135,0	133,5	7	18150,0	13878,3	63,6	11550,0
8,0	135,0	116,0	8	23550,0	18518,3	65,9	15521,6
9,0	135,0	111,0	8	28950,0	22958,3	68,2	19738,6
10,0	135,0	113,0	8	34350,0	27478,3	70,5	24201,1
11,0	135,0	125,0	8	39750,0	32478,3	72,7	28909,1
12,0	135,0	136,0	9+10	42450,0	35198,3	86,4	36661,4
13,0	135,0	161,0	10+11	45150,0	38418,3	95,5	43097,7
14,0	135,0	169,0	11	47850,0	41798,3	100,0	47850,0

Table 2.- Value Analysis

In the diagram below (Graph 1) the trends are shown over the project. The planned cost ended up being higher than the actual cost. The earned value shows the relationship between the money spent in the project and how much work has been accomplished. In our case it is below the actual cost between week 1 and week 12. This means that the project is spending more than was budgeted to achieve the work performed to date. It also shows the project is running behind schedule. After week 12 the earned value is behind of the schedule but spending correctly.



Graph 1.- Value Analysis

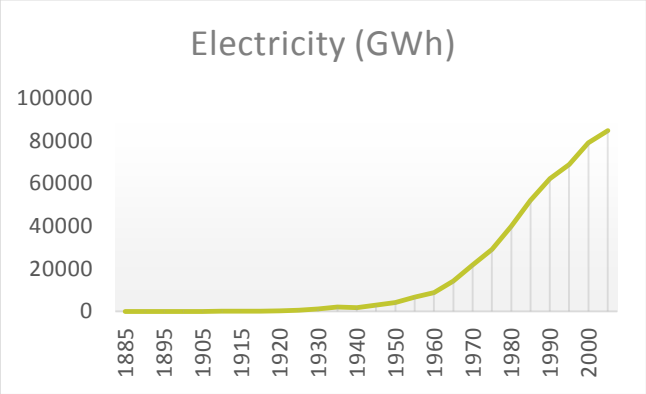
2. RESEARCH

2.1.ENERGY AND ENVIRONMENT IN FINLAND

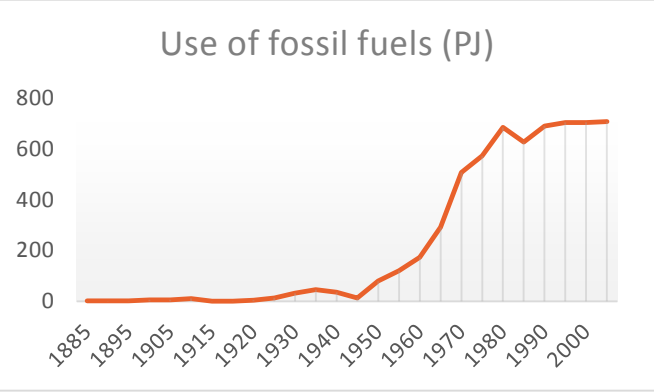
2.1.1. EVOLUTION OF ENERGY CONSUMPTION AND ACTUAL CONSUMPTION OF ENERGY IN FINLAND

THE EVOLUTION OF THE FINNISH ENERGY CONSUMPTION SINCE THE 20TH CENTURY

After 1917, Finland became independent and had to develop its own management of energy. At that time most of the timber felled each year was used as firewood. This utilization of wood quickly decreased after the Second World War due to the massive use of petrol. The use of fossil fuels has grown very fast after 1960 until the energy crisis in 1970, which slowed down all the Finnish activities. During a long period the most part of Finnish electricity was produced by hydro power, until 1960. Thermal power plants were first working with coal and oil. After 1970 the first nuclear power plants appeared. (1)



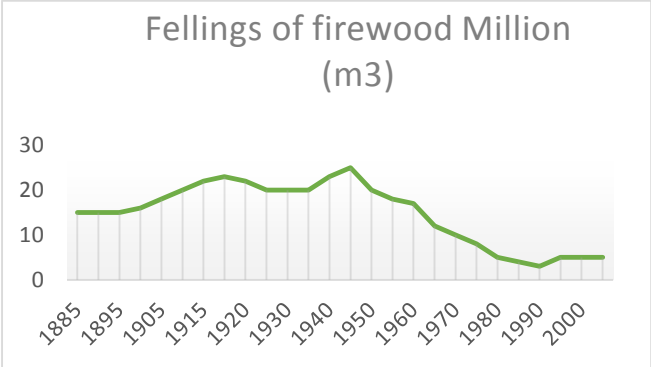
Graph 2.-Finnish consumption of energy (stats.fi)



Graph 3.-Finnish consumption of fossil oil (stats.fi)

WOOD CONSUMPTION

In 1917, after the independence, annual felling from forests amounted to nearly 30 million m² and today this number has increased up to 60 million. This is still less than the natural increment of the Finnish forests. Furthermore Finnish industry imports about 16 million m² of wood more. In 2005 1/5th of the energy consumed in Finland was created by wood combustion and all the wood by-products. The goal of the Finnish government is trying to reduce the wood consumption and make its wood industry more efficient and clean for the environment.

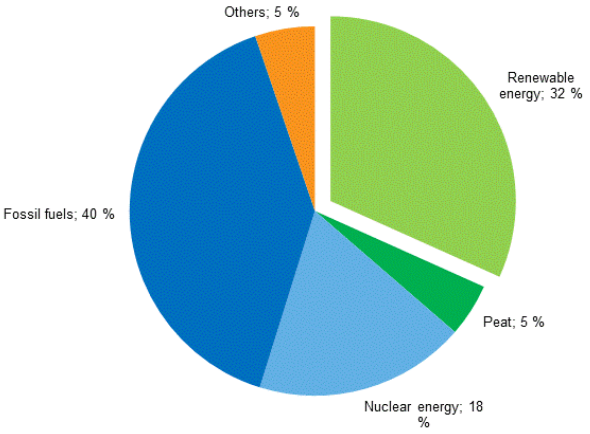


Graph 4.-Data from stats.fi

The wood can be used in a lot of different ways, it can be burnt, used in construction, to create paper or to create bio fuels. UPM uses the by-products of the pulp production to create bio fuels, their factory is directly supplied with the trash of paper companies all around Finland. The result is a biodiesel called UPM BioVerno. UPM claims this biodiesel should be 80% less polluting than normal diesel and usable in every modern diesel engine. (2)

FINNISH ENERGY CONSUMPTION AND ENERGY POLICY

Because of the wood and forest culture, Finland still uses a lot of fossil energy, especially from the Finnish wood production and all its by-products. Nonetheless, it is still a good student compared to the others European countries. For example, the European commission ordered all the countries to increase their share of renewable energy by 20%, yet Finland fixed the goal at 30% and reached it.



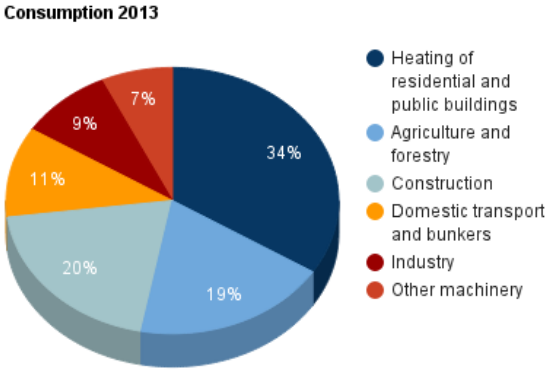
Graph 5.- Energy production in Finland (stats.fi)

The government committed to promoting and helping all the projects which are contributing to reduce the consumption of energy from power plants, such as the installation of heats pumps, solar panels, and wind turbines. Finland will also increase the utilization of biomass and biogas and stop using fossil oil for heating by 2020. A project with off-shore wind power capacity is in development and the use of recycled fuels like biodiesel will grow with 150% by 2020.

All these actions show that Finland is ready to reach the gap of a new way of thinking and using energy. (3)

This chart shows the consumption of different sorts of energy in Finland. It shows that stopping the use of fossil oil for heating can represent a change about 34% in Finnish use of energy.

As Finland is a country really oriented face of the nature, the people behavior tend to reduce their impact on the environment. (4)



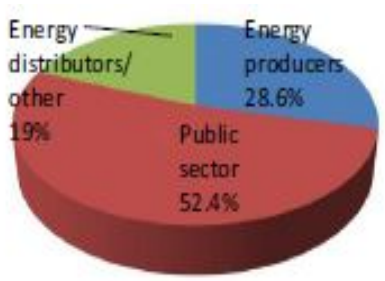
Graph 6.-Energy consumption by sector in Finland

2.1.2. AWARENESS OF RENEWABLE ENERGY

Working on a process that is focusing on biodiesel doesn't only mean understanding biodiesel and all its elements but also understanding the consumers' attitude towards biodiesel. Ever since the introduction of renewable energy, there has been a lot of controversy about this topic. Mainly about the moral question of using food as a feedstock for energy. It is well known that social attitudes need to change in order to make more radical scenarios possible.

Research has shown that a lot of people still have a lack of knowledge about renewable energy. In such a way that most of the surveyed weren't able to answer some questions. This also causes some contradictory information. Most people are willing to pay more for green energy although they don't know what green energy exactly is or whether it is more expensive or not. Only few people were aware of different kinds of renewable energy, those who knew some types of green energy where mostly technical students. It's clear that the older someone is, the less they are aware of green alternatives. These people claim to rely on the government to improve the general awareness for these types of energy. (5)

Even though all respondents replied that green energy is important for them, only 66% is willing to pay more for green energy. An important fact is that the majority (62%) is willing to make an investment in renewable energy if the payback time is less than 6 to 9 years. Most people believe that investing in renewable energy in the present will be a good strategy to reduce energy cost in the future. These statements indicate that, despite low level of information, the majority of respondents has a positive attitude towards green energy. The most important factor that influences this attitude is the political preference of the respondent. Other factors are perception, fear and knowledge. These last three can be influenced by the government. This means that awareness campaigns can have a positive influence on the consumers' attitude and thereby on the use of biodiesel. (5)



Graph 7.-Who should take the first steps towards renewable energy? (6)

2.1.3. LEGISLATION EU + FINLAND

There are three big institutions that influence the decisions and protocols in the Finnish climate policy. The first one is the United Nations Framework Convention on Climate Change, the second and more recent one is the Kyoto protocol and the third influence is the EU legislation. Since most of the Finnish goals towards energy saving are based on the latter, this will be the main source for comparing Finland to the rest of the EU.

Just like the other EU-countries Finland adopted the targets set in the EU energy and climate policy for 2020. These targets state that each member is obliged to reduce emissions by greenhouse gas by at least 20% from 1990 levels. Further on it's expected that each state will increase the share of renewable sources to 20% and improve energy efficiency by 20%. These are the norms set for 2020, hereafter it's expected that the EU will set new norms for 2050. In order to keep up with these new norms and to use the current opportunities and benefits related to climate policy, the Finnish government has decided in 2013 to set higher targets for 2020. Whereas the EU states that the share of renewable energy sources in final energy consumption should be at least 20%, Finland has set the goal to 38%. Further on Finland has set the goal for the share of biofuels in transport fuels to 20% whereas the double of the European 10%-goal. In the calculations of the target, it's important to notice that when using biofuel from the second generation (produced from waste) or third generation (produced from algae), it will receive double points compared to biofuels from the first generation. The reason for this measure are other global concerns such as food supplies and deforestation. Considering the diversity of raw materials used for creating biofuels, Finland is doing fairly well. (6) (7) (8) (9)

Source of renewable energy	Year 2007 (PJ)	Target level for 2020 (PJ)	Increment (PJ)	Relative change
Black liquor	153	137	–16	–10%
Solid wood processing industry byproducts and residues	68	68	0	0%
Hydropower	50	50	0	0%
Firewood	46	43	–3	–7%
Forest chips (in heat and power generation)	22	97	75	341%
Recycled fuels	7	7	0	0%
Heat pumps	10	29	19	190%
Other renewable energy (includes, e.g. solar energy and agro-biomass)	3	1	–2	–67%
Biogas	2	4	2	100%
Wood pellets	2	7	5	250%
Wind power	1	22	21	2,100%
Liquid biofuels	0	25[a]	25	–
Total	364	490	126	35%

[a]The figure corresponds to approximately 15% of the projected fuel consumption in the transport sector in 2020.

Table 3.- Finland energy targets for 2020 (6)

One of the main reasons, aside from the legislation, is to increase the goals of energy production is the security of energy supply. During the winter months, Finland is highly dependent on other countries for energy. In order to be self-sufficient Finland is currently making big investments to increase the energy production. There are no fossil fuel resources in Finland so it is necessary to take the next step in investing in renewable energy. In these investments there is a lot of attention for the environment. It is expected that these new energy supply systems will play a big role in achieving the goals set for 2020 and 2050. (8) (9)

Finland is clearly making an effort to increase the use of biodiesel and thereby decrease the use of mineral oils. Apart from the carbon-based taxes on mineral fuels, there is a large support network for increasing the use of biomass. There are three main categories used to promote renewable energy and reach the targets. Feed-in tariffs and investment subsidies are used to increase the usage of renewable sources. Taxes are used to discourage the use of fossil fuels. (10) (11)

The feed-in tariffs are a support option for power plants that produce renewable energy and are approved by the system. In Finland renewable energy is mainly promotes by feed-in tariffs. With the help of a formula, the Energy Authority sets a feed-in tariff that is received per produced kilowatt on top of the market price. This helps to keep the price of green energy affordable for consumers. This tariff is granted for twelve years at most and paid from the state budget. (10) (11)

Investment subsidies are available for companies that are trying to achieve lower greenhouse gas emissions by adapting or building new power facilities and energy plans that use renewable energy sources instead of fossil fuels. Projects that promote or produce green energy are also eligible for grants. These grants can be handed out to companies but also to municipalities and communities. The rule is that at least 25% of the financing must come from non–governmental sources. Investments that are directly related to building new facilities can receive a grant up to 30% of the total cost. If the project uses new technology, it is possible to receive up to 40% of the investment cost. Farmers are eligible for help if they have power plants that use either waste or renewable sources. The help can be in the form of a grant, lowered interest rates or a loan. (10) (11)

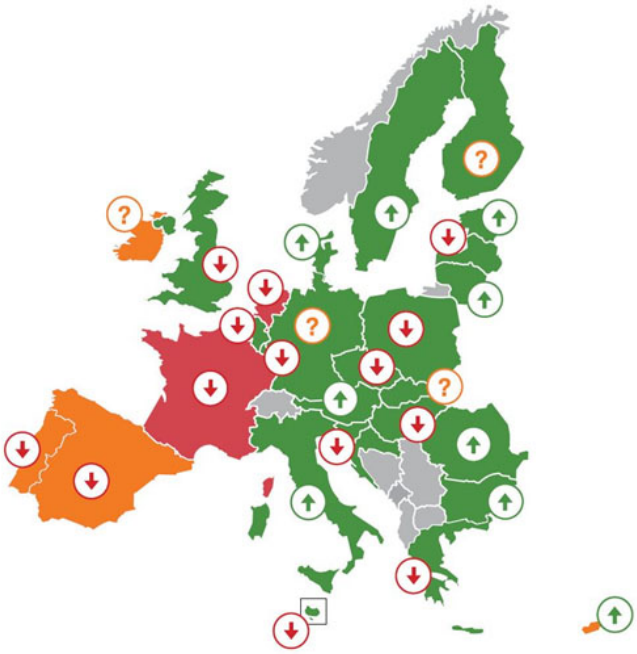
Both consumers and producers of energy are encouraged to use renewable energy by taxing energy sources that produce more greenhouse gasses than renewable sources. In Finland all fuels are taxed based on use, energy content and CO_2- emission. Coal based fuels and petrol are taxed the highest, biofuels are taxed the lowest due to low CO_2-emission. Retailers are bonded to The Act on the Promotion of Biofuels in Transport which states that a certain percentage of their total quota must be from biofuels. These biofuels need to meet the directives set in the fuel quality directive. This set of rules covers both sustainability and environmental directives. The percentage will be raised from 6% in 2011 to 20% in 2020. If the producer fails to fulfill the given percentage he will be held liable and receive a fine. The Fine will be proportional to the quota the retailer has failed to fulfill, each mega joule is charged with 0.04 euro. (10) (11)

Obligation period	Quota obligation
2011-2014	6.0 %
2015	8.0 %
2016	10.0 %
2017	12.0 %
2018	15.0 %
2019	18.0 %
2020 and afterwards	20.0 %

Table 4.- Finland quota obligation

It can be said that Finland is well on its way to reach these targets. The environmental opportunities are being well used, for example the increasing use of wood-based biofuels. Further on there is a large support network that will both increase the usage of biofuels and decrease the amount of fossil based fuels. However, according to the recent EU-reports it seems that Finland still has a long way to go if they want to meet their targets. In illustration 3 all EU-countries are shown in a certain color that indicates what the expectations for this country are. The biggest problems for Finland, mentioned in the report, are the lack of transparency in the support scheme. Finland aims too much for big companies and tends to forget about support for the smaller producers. Another problem is the administrative process to register a process or project. The result is that the EU's opinion is that Finland is reluctant to implement new technologies.

Even though Finland has set the goal for biofuels higher than other EU-members, there are a lot of problems with the infrastructure and supply. There are very few locations where it is possible to obtain 100% biofuel. The reason for this might be that a lot of people are reluctant to use 100% biofuels, even if they are cheaper. Suggestions made by the EU are to focus more on small-scale RES-projects and inform the people better about the support they can receive. Another suggestion is to review the rules and regulations to make it easier for producers to register to the network. (12)



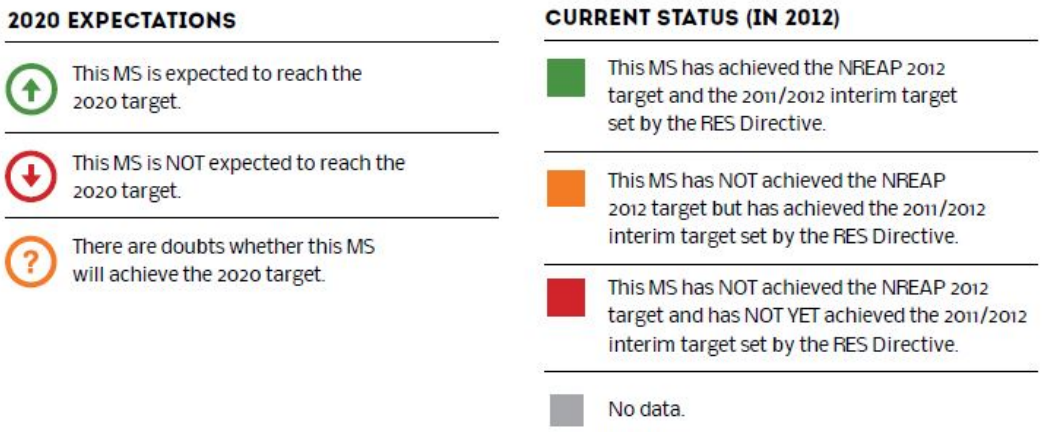


Illustration 3.- Expectations of targets and current status for Europe (12)

2.2.BIODIESEL

2.2.1. INTRODUCTION TO BIODIESEL

Bio fuels are liquid or gas fuels that are not derived from petroleum-based fossils fuels. It is important to know that these kind of organic fuels are classified in three types:

- First generation bio fuels: This kind refers to bio fuels produced from food crops and animal fats. For example **biodiesel**, vegetable oil and biogas are part of this first generation bio fuels.
- Second generation bio fuels: The origin of this type of bio fuel comes from waste biomass, making them a good sustainable solution. Some kinds of alcohols are included in this topic, such as ethanol and also diesel derived from wood.
- Third generation bio fuels: Third generation bio fuels are the less common fuels nowadays compared to the first and second generation bio fuels, and are made from algae cultivated by humans. The carbohydrates extracted from these microorganisms are used to make various fuels. (13)

Biodiesel ➔ The Department of Energy's Alternative Fuels Data Center define Biodiesel as: "Biodiesel is a domestically produced, renewable fuel that can be manufactured from vegetable oils, animal fats, or recycled restaurant greases." (14)

Biodiesel is the most common bio fuel that can be found at the present. It refers to a diesel derived from vegetable oil or animal fat consisting of long-chain alkyl (methyl, propyl or ethyl) esters. Biodiesel is made to be tapped in standard diesel engines, it can be used alone, or it can be blended with petro-diesel. (13)

Depending on the country, the biodiesel is derived from different sources. For example most biodiesel in the U.S. comes from soybean oil (Soy Methyl Ester, SME). In Europe the sources of biodiesel are more diverse, but most of them come from rapeseed oil (Rapeseed Methyl Ester RME). Palm oil based biodiesel is gaining popularity because of his cheap production. It is also important to say that the recent increase in the price of soy oil have done that the animal fats derived biodiesel are being more seriously considered. Bio fuel coming from animal fats has different properties than vegetable oil based biodiesel, for example the first one has less cold flow and stability properties. (15) (16) (17)

The most common way to obtain Biodiesel is throughout the process known as **transesterification**.

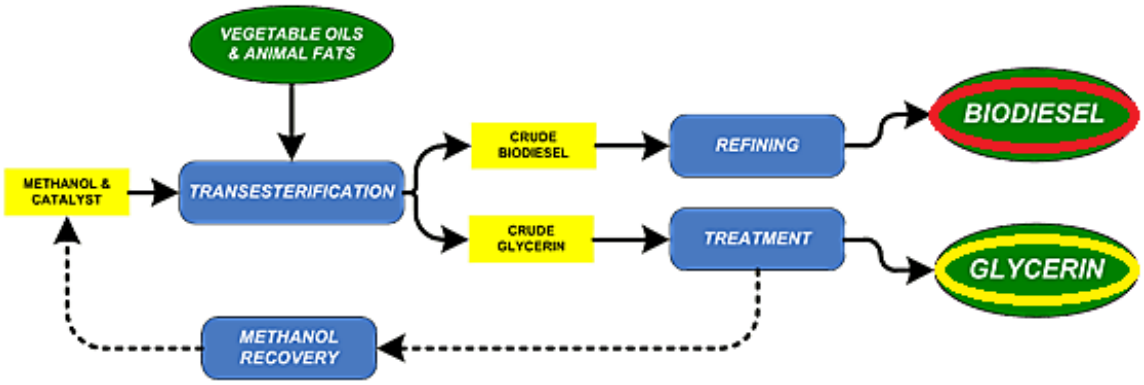


Illustration 4.- Process to obtain Biodiesel. (73)

- **First Stage**

The vegetable oil or the animal fat is pre-heated in the temperature range of 90-100°C for elimination of water content. The crude oil is treated with an acid catalyst (H_2SO_4) and alcohol in the temperature range of 55-60 °C to avoid soap formation during the transesterification method. After 3h of reaction two layers can be differenced, the alcohol fraction (top layer) and **transesterified oil** (bottom layer).

- **Second Stage**

The methanol and a base catalyst (KOH) are mixed with the **transesterified oil**. At the end of the reaction between this products (65°C, 3h) will appear the monoester (**biodiesel**) and glycerol.

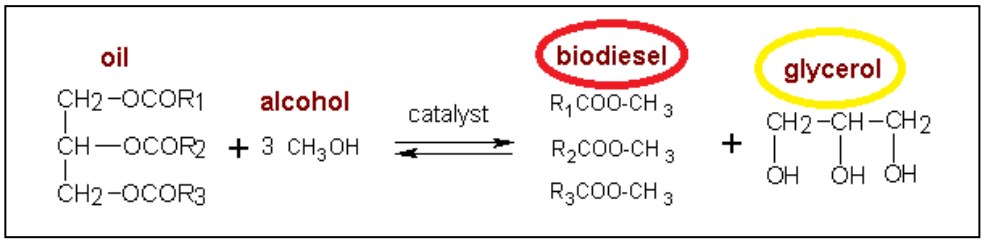


Illustration 5.- Chemist reaction of Transestirification. (74)

- **Third Stage**

The **biodiesel** is washed with hot distilled water as many times as needed to remove all unreacted triglyceride, alcohol and salt. After all, the oil is heated at 70-95°C to remove moisture.
(13)

2.2.2. ADVANTAGES OF BIO DIESEL

ENVIRONMENTAL NON-IMPACT

This bio-fuel is renewable and non-toxic, principle reason of the fast production increasing in Europe, Asia and United States. It is also important that it gives off less gaseous pollutants than common diesel. The CO_2 emissions from the biodiesel fueled engines can be treated as ‘‘zero net carbon emissions’’. The right definition of this is; when burning bio diesel in the engine it releases CO_2, however this carbon dioxide has been sequestered from the atmosphere for the growth of vegetable oil crops. It is like a cycle. (13). "Bio diesel reduces net carbon dioxide emissions by 78 percent compared to petroleum diesel" is the conclusion of a study sponsored by the U.S. Department of Energy and the U.S. Department of Agriculture (USDOE/USDA). (18)

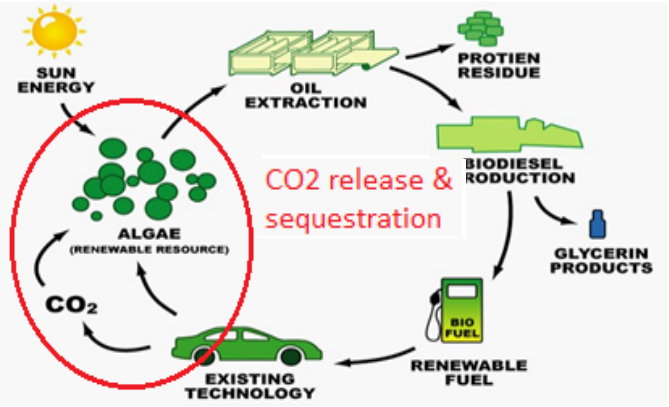
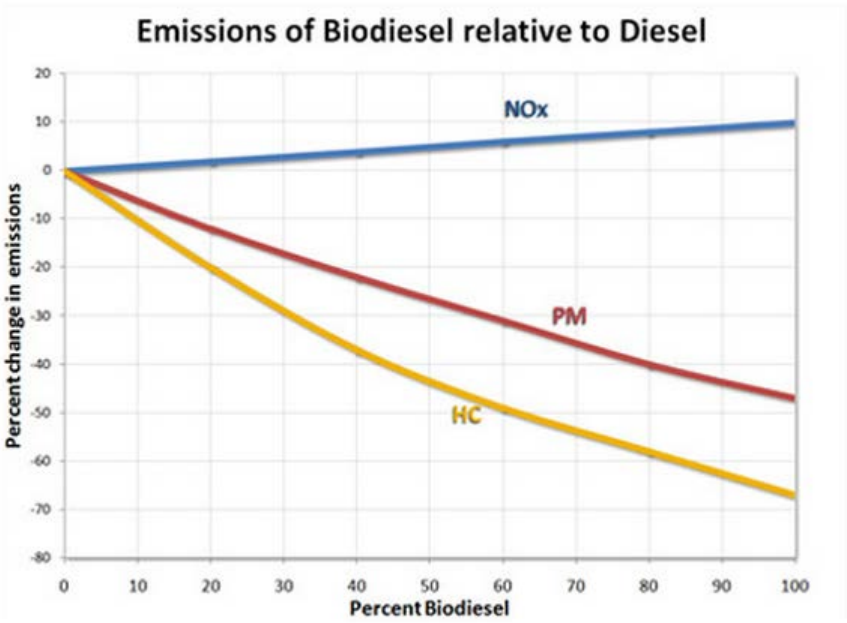


Illustration 6.- CO_2 release and sequestration coming from bio diesel.

The biodiesel emissions of contaminant agents compared to usual diesel are much inferior, for example there is a high diminish in the emissions of hydrocarbons (HC), carbon monoxide (CO), particulate matter (PM) and Sulphur dioxide (SO_2). No more than NO_x emissions are considered to increase because the oxygen content in biodiesel is higher than diesel. (Graph 8)



Graph 8.- Average emission impacts of biodiesel engines (18)

Representative engine combustion reaction for biodiesel:

$$\text{Biodiesel} + \text{air } (O_2+N_2) \rightarrow CO_2 + CO + H_2O + N_2 + O_2 + (HC) + O_3 + NO_2$$

(13)

BIODEGRADABILITY

The Biodiesel has a high content of oxygen which gets a better biodegradation process. It is also not dangerous to handle and transport because it is as biodegradable as sugar and the flashpoint (*lowest temperature at which it can vaporize*) is superior to the conventional diesel fuel. Glycerol, the last product obtained in the transesterification, has many uses. It can be converted to glycol, propanol, hydrogen, syngas and is also used as a feed for certain animals. (13)

2.2.3. USING PURE BIO DIESEL

B100 refers to pure bio diesel, 100% of bio fuel, it is similar to petroleum based diesel, so it can work in normal engines without important modifications. However, using this bio fuel in its pure form has several disadvantages. That is the reason why nowadays it is not usually used as a stand-alone fuel. Before talking about the properties and the usage requirements of this non-blended bio fuel it is good to define several concepts which are characteristic of biodiesel.

- **Cloud Point**: It is the low temperature at which it can be seen wax crystals appearing on the surface of biodiesel. This solid crystals will choke the filters and the fuel won't reach the engine. (13) (15) (19) (20)
- **Pour Point**: This factor refers to the cold temperature at which the fuel will face difficulties to move. It will become gel, so this point establish the minimum temperature value at which the fuel can be pumped. (13) (15) (19) (20)

In the next table (Table 5) it is compared some properties between normal diesel, B20 and B100.

	Petro Diesel	B20 - Petro/Bio Blend	B100 - Neat Biodiesel
Viscosity [cSt]	2.8	2.9	4.1
Density [kg/m^3]	856	862	886
Sulfur [%Wt]	0.048%	0.037%	0.000%
Oxygen [%Wt]	0.000%	2.100%	11.000%

Table 5.- Different properties of Pure Biodiesel (B100), B20 and conventional Diesel.

B100 has a higher viscosity, higher density and a higher percent of oxygen. The viscosity affects directly to the quality of fuel atomization in the combustion chamber. If the temperatures goes down the viscosity will increase to higher values causing stress and pressure on fuel pumps and fuel injection systems. B100 has about 11% oxygen by weight, as well as zero percent of sulphur. This properties make a more complete combustion and a decrease in contaminating emissions compared to conventional diesel. This high percent of oxygen generates problems about the storage, fuel oxidation and microbe growth. Those problems will be defined later in the report. (21) (15)

2.2.4. COMPANIES DOING BIODIESEL

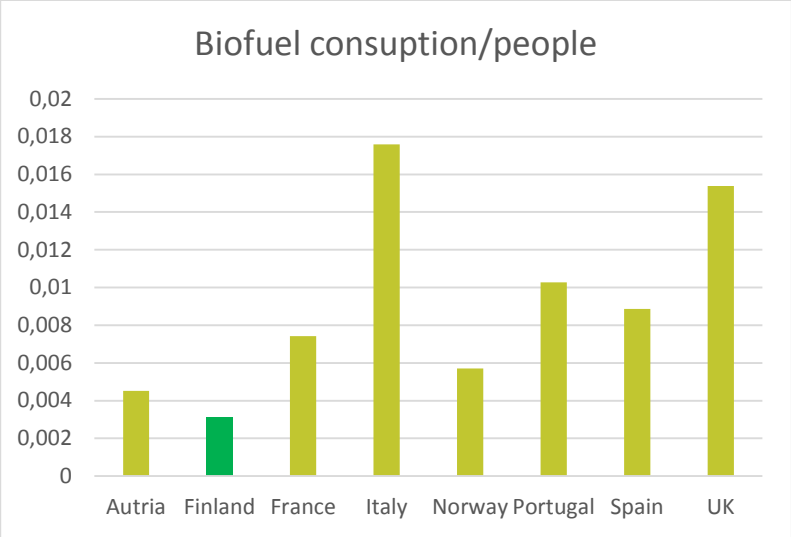
The EU parliament set the goal at 5.75% for the use of biofuels in 2010. Finland reached it by producing a biofuel with the same price as the others European countries. A lot of companies started producing biofuels with their own process, for example ST1 produces it from food industry waste, Neste produces 0.34 million tons each year by using vegetable oil. Today the main source of Biofuels is still palm oil. UPM, a large paper company, discovered an interesting process that uses the waste of the paper-process (tall oil) to create biofuel. Due to a lot of financial problems in biofuel companies, the Finnish government tries to help all the projects related to biodiesel production. Yet the price of biofuels remains higher than the fossil fuels but they are still ways to find a cheaper one. (3)

Different companies doing biofuels in Finland

- Neste Oil Corporation (www.neste.com)
- Neste Markkinointi Oy (www.neste.fi)
- St1 Oy (www.st1.fi)
- Suomen Osuuskauppojen Keskuskunta SOK (www.sok.fi)
- Oy Teboil Ab (www.teboil.fi)
- Finnish Oil and Gas Technology Association (www.oktry.fi)
- VTT Technical Research Centre of Finland
- Greenvironment Oy
- BioGTS Ltd.
- Ahlstrom Filtration
- Ductor Corp.
- UPM
- SEO - http://www.seo.fi/etusivu
- Teboil
- ABC KPO
- FEORA

Even if all these companies produce biodiesel only few of them can sell it pure to professional workers.

2.2.5. STUDY OF THE CONSUMPTION OF BIOFUELS IN EUROPE.



Graph 9.- Consumption of Biodiesel in Finland (stats.fi)

This data from graph 9 comes from the Finnish government database and shows us that Finland is actually lagging behind a lot compered to other European countries in concern to biofuel consumption. But today a lot of Finnish companies have started to develop their own biodiesel production by recycling trash. Feora for example uses by products from the fur industry. (22)

Comparison of the prices between Fossil and Bio fuels

Graph 10.-Price of biodiesel in Finland (Neste.fi)

For this comparison, data from Neste Oil company and from different European gas stations was used. There is a noticeable price difference in the price per liter.

Biodiesel: 1.55 € VS. Diesel: 1.21 €

The conclusion of this study is that fossil diesel is 22% cheaper than biodiesel. This is the main reason why people who want to use the biodiesel need support from the government but after the interview with Feora, it seems that it is possible to find pure biodiesel for **15 cent/L** less than normal diesel. (23) (22) (24)

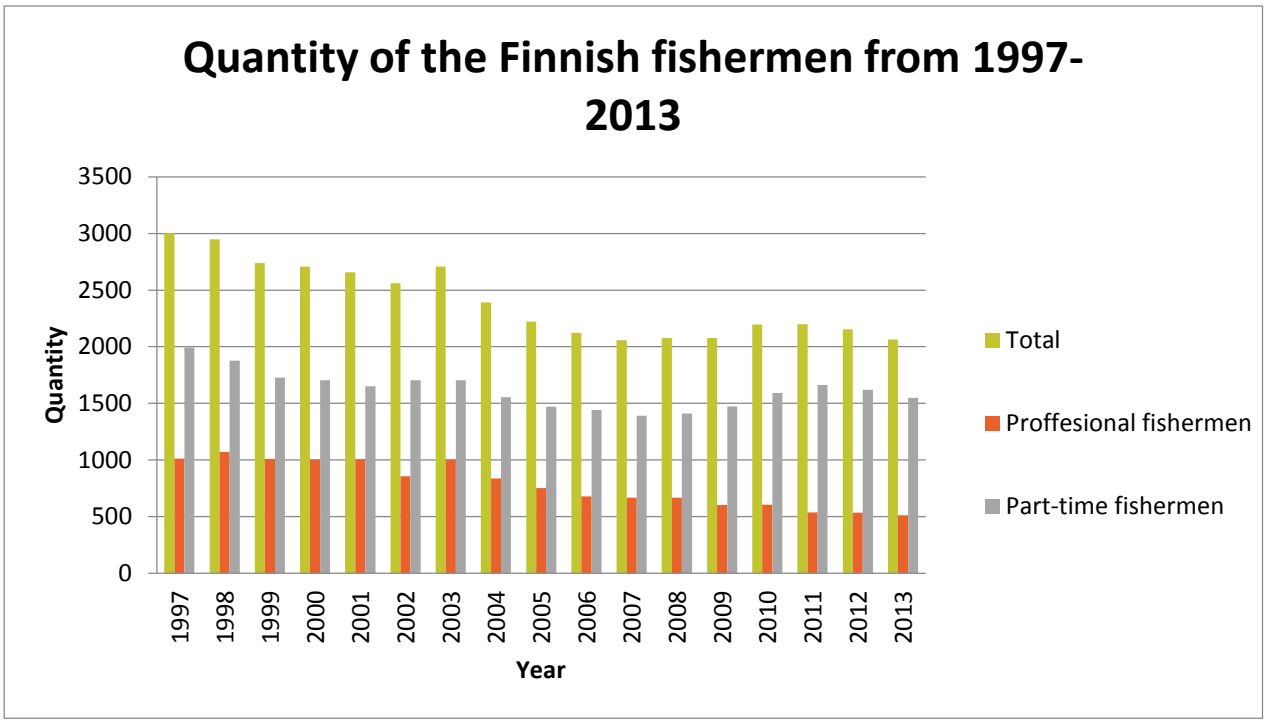
2.3.FISHING INDUSTRY IN FINLAND

2.3.1. FISHERMEN, SITUATION AND LAW

2.3.1.1. THE FISHING INDUSTRY IN FINLAND

Finland has about 187 900 lakes inland as well as 1 100 km of Baltic Sea coastline, which includes the archipelagos, and 674 rivers that covers about 25 000 km. These correspond to 34 330 km^2 meaning about 10 % of Finland's total area and probably the main reason why Finland is usually called the land of a thousand lakes. With its large selection of lakes and access to the sea it's only natural that fishing is a natural part of the Finnish culture. So it's only natural that the Finns have a long history with fishing trade and today the Finnish fishing industry can be divided into fishing, fish breeding, hydroponics and stores. (25)

Fishing can be done by professional fishermen (commercial fishing) and the leisure fishermen. The difference between these two is that professionals sell their catch and the leisure fishing is not done for profit. Today there are about 2 000 registered professional fishermen in Finland but sadly the numbers has been declining since late 1990s (See graph 11), but then again the professional fishermen can be split into full time and part time fishermen. For anyone to be a fulltime fisherman the Finnish law requires that the persons total income should contain about 30 % from fishing and for the part time fishermen's total income from fishing is less than 30 %.



Graph 11.-Quantity of fishermen (1997-2013) .- (26)

The reason for declining quantity of the Finnish fishermen is because of the rise of middle-aged people and the loss of interested to fishing from the younger generations. Another reason is the economical one, the profitability problems with the rising expenses like fuel and equipment's and the regulations from the EU and the government. (27)

Like previously mentioned the fishing has always been a part of the people living in Finland and the country offers many opportunities for catching various species of fishes. There are approx. 60 species of fish in Finland and if the occasional visitors are counted in the species of fish will rise approx. to 100. The most important species of fish for fishermen are for example following:

- Baltic herring

Illustration 7.-Baltic Herring .- (Varsinais-suomi.fi)

- White fish

Illustration 8.-White fish

Illustration 9.- White fish

- Perch

Illustration 10.- Perch.- (Gnatoutdoors.wordpress.com)

- Salmon

Illustration 11.- Salmon.- (Aktivaaventyr.wordpress.com)

The fishing methods that the fishermen use can be divided into two parts. They are passive and active fishing. The passive fishing includes cage fishing, trap-net fishing, hook fishing, net and mesh-fishing. These methods don't demand a lot of fuel unlike the active fishing like trawling and purse seine fishing. (25) (28) (29) (30)

Illustration 12.-The active fishing methods (29)

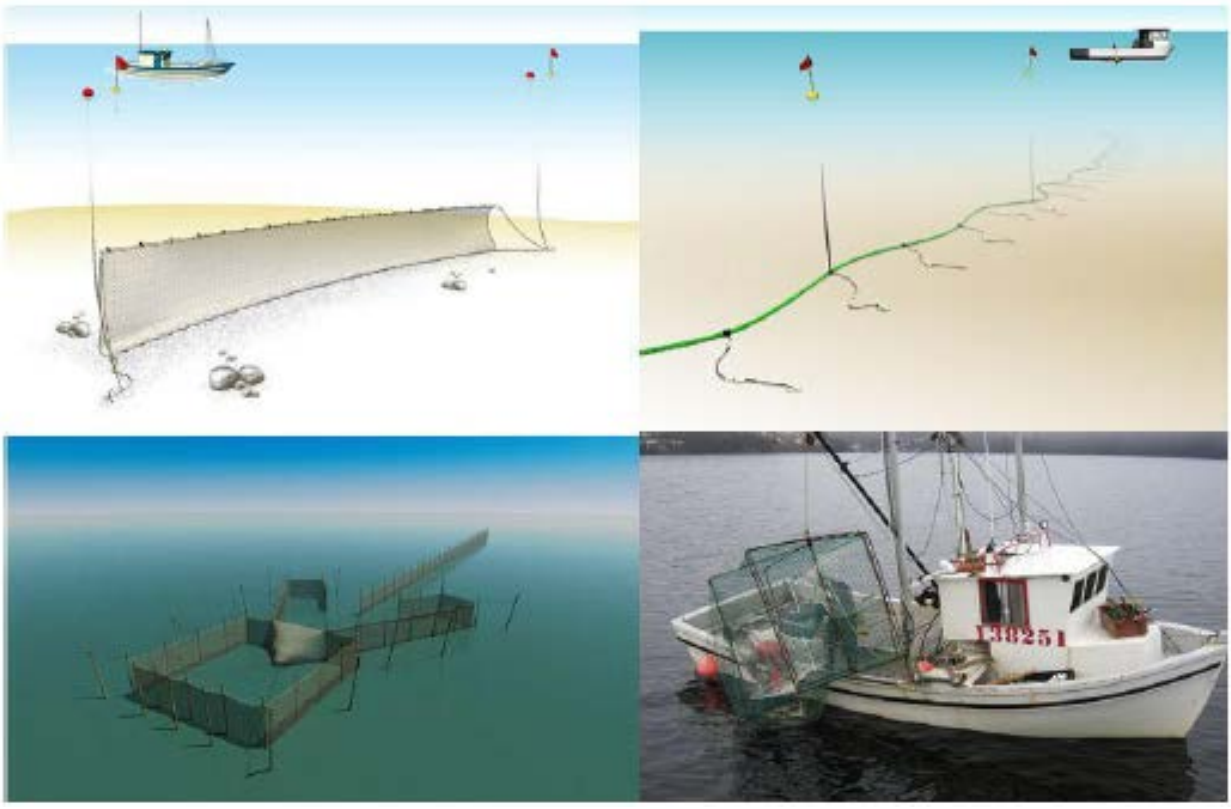
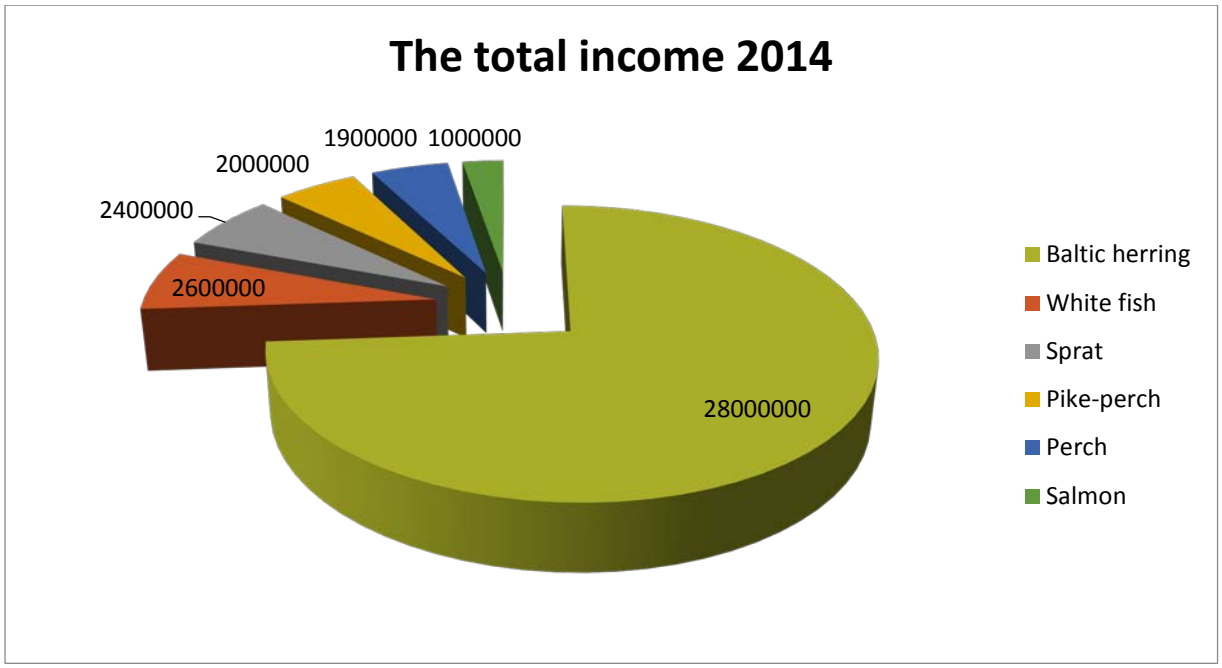


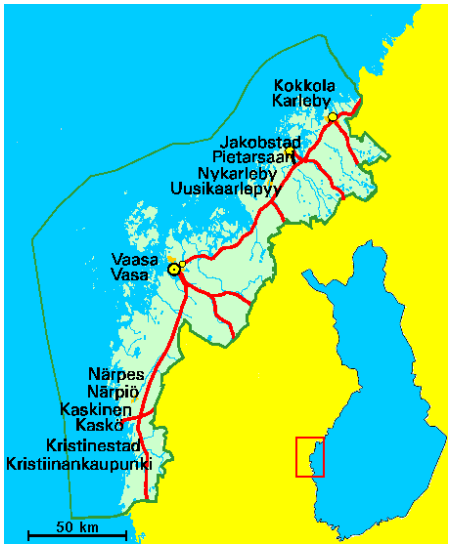
Illustration 13.-Passive fishing methods (29)

The total income from commercial fishing was 148 million kilos last year 2014 and the catch was 10 million kilos more than the year before but the total value was 6 million Euros less compared to the previous year. In 2014 the total income was 40 million euro and in the pie chart (Graph 12) what the income was from the different species. (28)



Graph 12.-Total income 2014 (31)

FISHING IN OSTROBOTHNIA



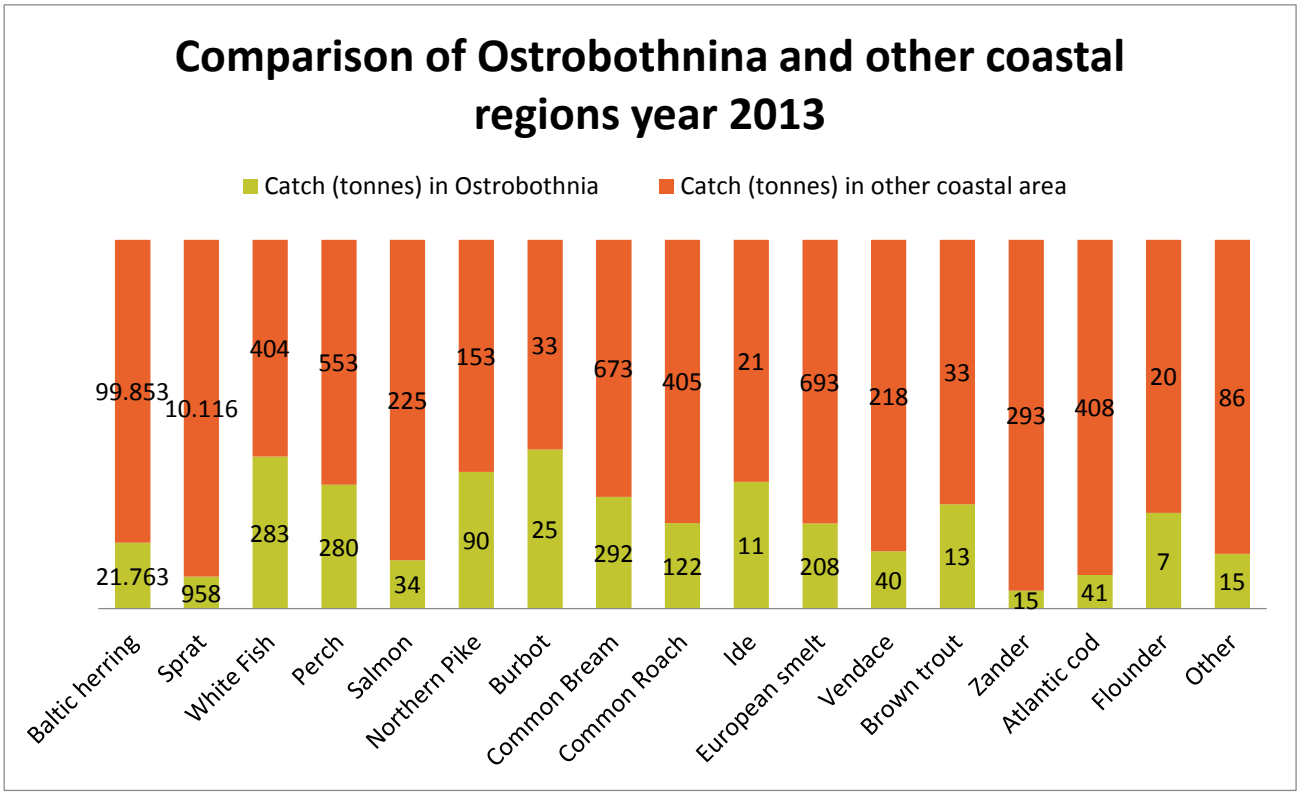
This report will mainly focus on the fishing industry in Ostrobothnia, which is located in Western Finland. Ostrobothnia region is split into four sub-regions but this report will mainly focus on the Vaasa and Jakobstad sub-region. The two other regions are Sydösterbotten and Kyrönmaa. The fishing area in Ostrobothnia reaches from Kokkola in the north to Kristiinankaupunki in the south. (29)

Illustration 14.- Map of Ostrobothnia.- (Pinterest.com)

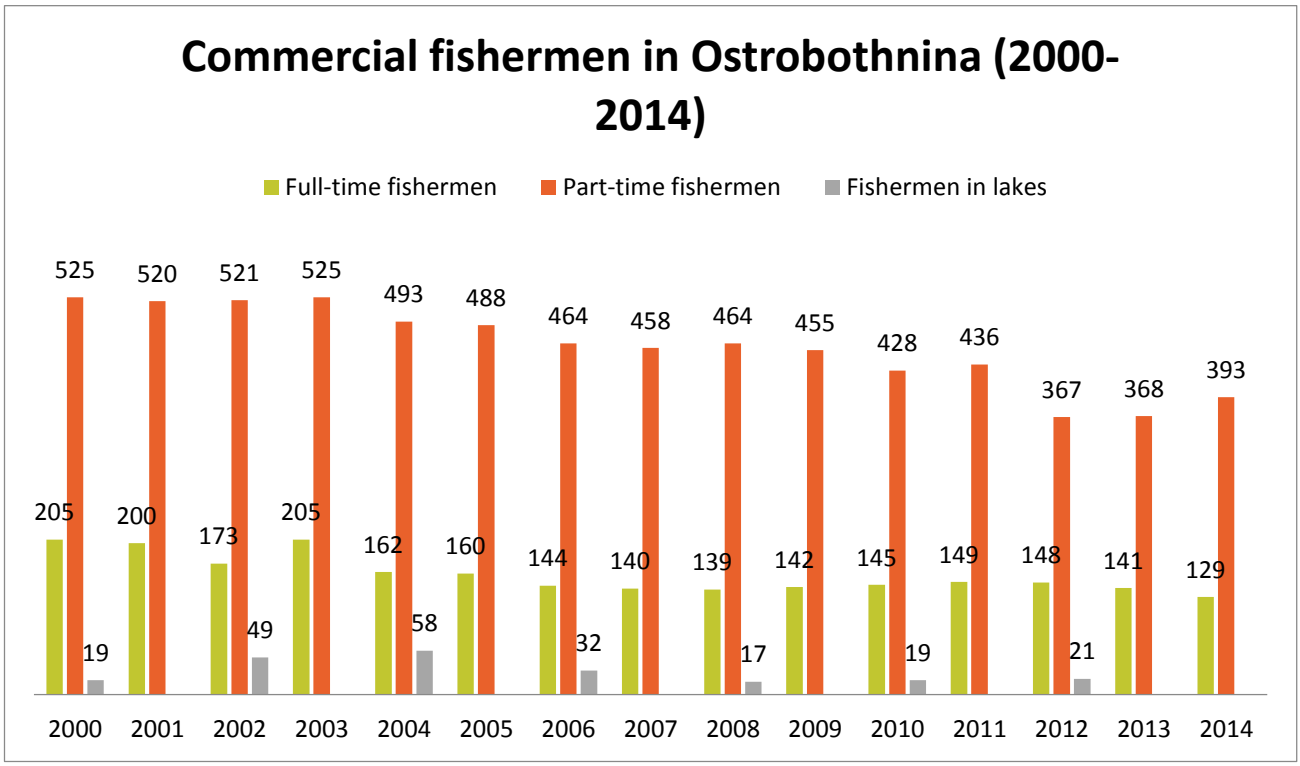
The fishing industry in this area is large if looked from the national perspective. Of all the country's professional fishermen, 24 % are from Ostrobothnia. Most of the fishing equipment industries are located in this area and there are also approximately 30 wholesalers and processing companies. There is about 10 fish breeding companies in this location and some lobster and fish spawns and approx. 12 companies who operate in fishing tourism. This can be seen in the table 6 that takes up the fishing industry in Ostrobothnia in numbers. The fish breeding is mostly located in south Ostrobothnia and the breeding is concentrated on rainbow trout. The total production reaches almost 700 ton and the value is ca. 2.5 million euros. (29) (30) (32)

The fishing industry in Ostrobothnia in numbers in 2013	
760	fishermen
170	professional fishermen
970	Fishing boats (size between 7-10 meters)
approx. 20	Fishing ports
approx. 30	Wholesalers and Processing companies
approx. 30	Retail sellers
6	Fishing equipment industries

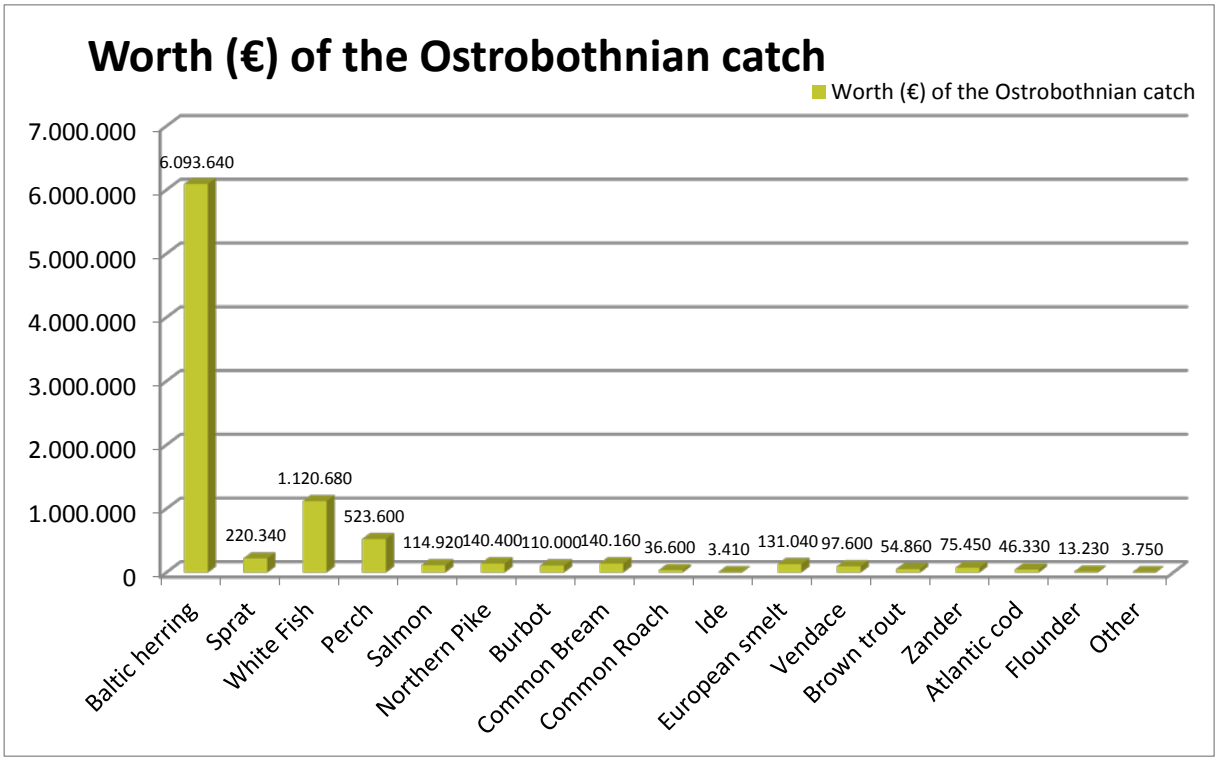
Table 6.- The fishing industry in Ostrobothnia in numbers in 2013



Graph 13.-Comparison between Ostrobothnia and other coastal regions (2013) (5)



Graph 14.- Commercial fishermen in Ostrobothnia (2000-2014) (5)



Graph 15.- Value of the Ostrobothnian catch (5)

2.3.1.2. FINNISH FISHING INDUSTRY AND THE LAW

The fishing laws in Finland can be quite complex sometimes. According to Finnish law the fuels used in fishing vessels are tax-free when they are used in commercial fishing. Commercial fishing is fishing done by someone that gets their income, or a major part of their income, from commercial fishing or breeding of fish.

The total income from fishing has to be at least 30% of the total income. The fisherman/-woman has to be in the commercial fishers' registry, and the vessel used for fishing has to be in the fishing-vessels registry. The person has to be written in these registers no later than when fuel is acquired for the vessel. (27)

The Finnish fishing industry is regulated by the government and from the European Union through the Common Fisheries Policy (CFP). CFP's goals are to ensure that the usage of the fishing is sustainable. They also wants to ensure that overfishing is prevented by regulating the fishing quantity that is made by the EU, also preventing overfishing so it doesn't threat the fish population size and productivity over the long term. The most important species of fish are the Baltic Salmon, Codfish, Baltic herring and European sprat.

The reform of CFP changed the management system also allowing the EU countries greater control at national and regional levels. This change resulted that the water area evaluation can be divided into ocean (sea) and lake areas.

Finland's goals with the CFP's reforms has been from the regional approach. The approach has also taken shore and aqua cultural meaning in Finland into account. The Finnish ministry of agriculture and forestry is the "middle hand" between the Finnish fishermen and the CPF and anything associated to the EU's legislation concerning the CPF. (33) (34)

2.3.1.3. NATIONAL LEVEL

The commercial fishing in Finland is regulated by the laws and the rules concerning fishing. These laws and regulations define e.g. fishing rights, the allowed quantity of catches, the fish's minimum sizes and the protection time. Right now there is going on a renewal of the fishing laws in Finland and it will be in effect by the beginning of 2016. Sometimes the council of state or the Finnish ministry of agriculture and forestry can set out temporally regulations within the fishing industry.

- **Fishing rights holders**

The right to carry on with fishing and the rules of fishing in the area is done by the ones who own the water area. The owners can be a private person/estates or the government. These partners create a town council that functions according to the Finnish law, regarding the municipality community and the fishing laws.
The owner is responsible to arrange the fishing in the area so it fits into the fishing regulations in the area and to secure the sustainability and the variability in the area. The owner is also responsible to see that overfishing doesn't happen and that the nature's versatility remains.
It's also possible to rent the water area to the commercial fishermen but the contract has to be on a fixed-period and last at least 5 years and up to 20 years.

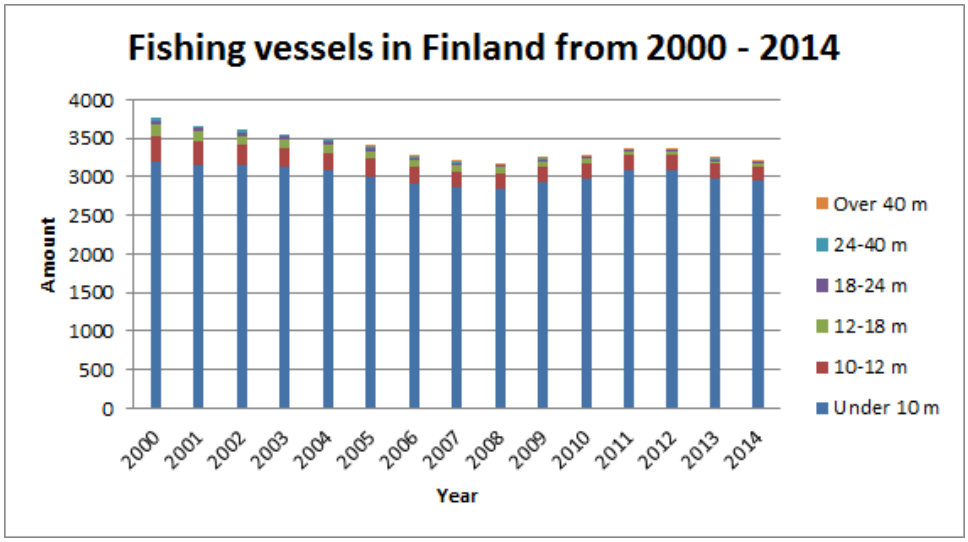
- **Public authority regarding fishing in Finland ELY-center**

ELY-center is the public authority regarding the fishing in Finland. Some of their task is to decide the regulations regarding the fishing industry such as fishing permission's and bans. Also monitoring the amount of chough fish and other tasks that includes in the Finnish fishing law and EU's common fishing politics. ELY also maintains the register over commercial fishermen and fishing vessels.
(27) (34)

The ELY- center is the public authority regarding the fishing in Finland. The business economy is divided into fishing, aquaculture and selective breeding of the fish and also the fishing agents.

Fishing vessels register is voluntary for the ones that are fishing in the lakes but if the fishing is done in the sea area it's compulsory to register into the fishing register. When the commercial fishing is performed in the seas the fisherman will get a register plate, which also functions as the fishing license. The benefit of registration is tax return for fuel costs and the fisherman has the right to investment support. The fisherman will also get some useful information from the authorities. (27)
The register is divided into three groups. They are:

- Fishing vessels that the length is under 12 m
- Vessels that are over 12 m
- Fishing breeding vessels



Graph 16.-Fishing vessels in Finland (9)

The regulations of fishing amount is set in case to prevent overfishing. The regulations of fishing catches can be monitored by the reports given by the fishermen. The fishermen are obligated to report their caught amount. Even the salesmen or the breeding companies have to report the amount of fish they are buying. If this is not done the person in question can get a fine or be forced to pay back the EU's fisherman support or he/she won't get support at all.

- **Fishing inspectors**

The supervision that the fishing laws are followed is done by the local police, border guards, customs (Tulli), ELY-center and the ELY's approved fishing inspector. The fishing inspector has the right to inspect that the caught fishes are acceptable and they are allowed to take away illegal catch on the expense of the guilty party. Even the owner has the same right as the inspector and he can even take into custody the vessel that has been used while illegally catching the fishes. The equipment that has been confiscated has to be informed to the local police and the belongings have to be handed over to the police as well if charges are being pressed. The sentence for breaking the law is a fine or jail and the impoundment of fishing equipment. (34) (27)

2.3.1.4. BIODIESEL LEGISLATION IN FINLAND

Finland's goal for use of biofuel is to have at least 20 percent of all propulsion fuel to be some kind of biofuel by the year 2020. This can be done with the help of new and innovative technology, e.g. to start using second generation bio-fuels in time and to invest and research in the market. Second gen. biofuels are made of waste, food remains and cellulose. Using biofuel doesn't require that much change in the infrastructure as opposed to using electricity and gas, where you have to build electricity and gas stations.

The raw ingredients used in Finnish refineries for making biofuel are mostly from vegetable oil and animal fat.
The standard in use in Finland for biodiesel is EN 14214 from the year 2003 and the RES directives from the year 2009. There is also a law in Finland about the usage and distribution of biofuel and bio liquids.
The RES directive requires that the biofuel/liquid fulfills criteria's regarding sustainability when:

- The use of biofuels is included in the national mission to use renewable energy sources
- That national sustainability and obligation systems are used
- The use of biofuels / liquids gets financial support

To the sustainability criteria's include:

- The life-cycle greenhouse gas emission savings should be at least 35-50 % with effect from year 2017 and 60 % by year 2018 for sets of biofuel/liquid that the production started on or after 1st of January 2017.
- The raw material should not be taken from areas where the forest or wooded lands don't have clear marks of human activity or that the ecological processes have not been greatly disturbed. Also the areas meant for nature protection or highly biodiverse grasslands. The material can only be taken from protected areas if there is evidence that the natural process is not disturbed. The raw materials cannot be taken from wetlands, continuous forested areas or where the forest with canopy cover 10-30%.
- The materials should not be obtained from peatlands that has been drained since January 2008
- Agricultural raw materials grown in EU should be acquired according to the requirements and standards set for farmers and according to the criteria's for good agriculture and environmental conditions.

In the Finnish law about biofuels and bio liquids (393/2013), their requirements and sustainability are mentioned in the second chapter which is the decrease of greenhouse gases during the biofuels and bio liquid's life cycle and the origin of the biofuel / liquid. The third chapter of biofuel is showing that the criteria have been met by the business driver and that their sustainability system is up to standards to allow them to get a sustainability certificate that indicate such. (29) (35) (36) (37) (38)

2.3.2. INTERVIEWS WITH COMPANIES AND OTHER PROJECTS

2.3.2.1. FRENCH PROJECT

We tried to see if there were other project like ours being developed and we founded a similar project in the south of France: the I.T.S.A.S.O.A

This project was very similar to ours, the goal is also to use biofuels in the fishing industry, but in this region there are less issues with the climate. This means that they don't have to e.g. deal with extreme conditions and variations of the fuel viscosity.

Their project was different in a sense that they used pure sunflower oil in a separate tank with an automatic inboard system, which manage the transition between the two fuels. They didn't have to work in extreme climate, furthermore, as the tank is under the waterline, the temperature didn't reach below 10°c. So the only one issue was concerning the fuels viscosity but the system is programmed to inject fuel in a compatible way with the engine's operation.

With this kind of fuel, the consumption was reduced by 10% and the engine worked with low snap and less vibrations. They used a liner shell polymer 9.5 m (Nahikari) and a wooden hull bolincheur 11m (Lapurdi) on ITSASOA project, a 14.85 m gillnet polymer shell (Croesus) on the AREC project.

The engines we are working on right now are double carburetion Peugeot 45CV XUD7, Nanni Diesel 4200TD, Daewoo L 066TI and L136TI, RVI 450 hp Baudouin base.

The system heats the oil (plate heat exchanger) before triggering the injection in the engine (automatic dual safety system). In the case of double carburetion systems, there is no mixing (case of fishing vessels).

There are two different ways to mix the fuel: 30% PPO directly introduced into the tank either manually (70% diesel and 30% HVP) or automatically (setting of the mixture directly in the gun output with the system ERLA Technologies).

The problems encountered were more administrative than technical and with a cooperation between fishermen and farmer the cost of sunflower oil is really cheap. The only "help" that they had was a reduction of TIPP as that applied to FAME, but is reduced every year. The ITSASOA program is still ongoing, including through cross-border trade to acquire oil at a price equivalent to the GOP.

Both project are very close to each other but the French one doesn't have a problem with low temperatures. This interview was helpful to determine which kind of boat can use biodiesel and which kind of fuel is already used.

2.3.2.2. Neste

We also reached some Finnish companies to get more information about the biofuel market, and also practical information to know how the biofuel supply works.

Is it possible for the local fishermen to buy Biofuel from you directly do they have to use another way?

In theory, yes it is possible. In practice they probably would not buy quantities that would justify the logistics cost that they would have to pay. An easier way would be to buy Neste Pro Diesel, which always contains minimum 15 % of NEXBTL renewable diesel, often more. Pro Diesel is available at manned Neste Oil stations, and its logistics reach all of Finland.

Do you supply pure Biodiesel for engines (B100), or normally you supply some kind of blended fuel as B20?

This depends on the buyer: to other oil companies we may supply pure NEXBTL for them to blend. We can also supply ready blends. Above I have also described the Pro Diesel offering.

Are you supplying some "gas station" or the harbor directly or maybe the consumers?

Gas stations in Finland. Also directly to some B2B customers.

What are your tariffs for the biofuels?

That varies according to market situation and feedstock (raw material) price fluctuations. In all cases renewable diesel is more expensive than fossil diesel.

2.3.3. STATISTICS ABOUT THE ENGINES AND FUEL SYSTEMS

A diesel engine finds it place in the category Combustion Engines, the diesel engine is also known as a compression ignition or 'CI' engine. This means that the fuel that has been injected in the combustion chamber will be ignited by the high temperature created when compressing the air fuel mixture. This system works perfectly with petroleum fuels, mainly diesel.

Biodiesel can be used in pretty much every kind of diesel engine that runs on petroleum diesel. It's a different story when it comes to long term use, especially with older engines. In older diesel engines a lot of rubbers (natural, nitrile and butyl) are found which are vulnerable to degradation. Also certain metals (brass, bronze, copper, lead, tin and zinc) that are used in older engines can improve oxidation of biodiesel, which can lead to deposits that damage the engine. (39)

With new engines these problems are already solved in the development stage, and some manufacturers even approve the usage of biodiesel in the engine, but only when the standards of EN 14214 are fulfilled. The manufactures will recommend some actions that should be taken to run biodiesel successfully in their system. For example these are the recommendations from Volvo Penta. (40)

- After starting the usage of biodiesel for the first time in your system, replace the fuel filter after a short period of time. Biodiesel is an efficient solvent, which can dissolve constituents in the fuel system.
- Biodiesel can oxidize in the fuel system because it is does not have a long term-stability , therefore after a long period of time still standing the system should be emptied and flushed with normal diesel.
- To avoid leakage, all the rubber hoses and plastic hoses in the fuel system must be checked more frequently.
- Biodiesel reduces the lubrication capacity of the oil because of the higher boiling point, therefore lubrication oils and filters should be changed more frequently.

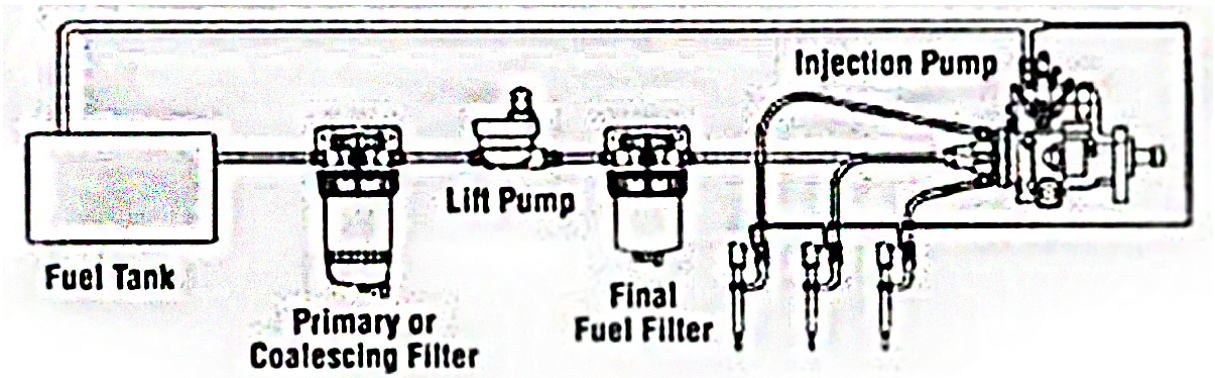


Illustration 15.- Diesel engine fuel system layout.

The basics of diesel engines used in fishing boats are not any different from the ones found in trucks, tractors and cars. The one thing that is different are the sizes, because a different size boat needs a different size engine. The size of the engine is often translated to engine displacement in litres and the amount of cylinders. Down below the amount and type of engines that are used in the fishing industry in Ostrobothnia are shown.

Engine	Model	Quantity	Total
Volvo Penta	6-cylinders	6	11
	4-cylinders	4	
	3-cylinders	1	
Perkins	6-cylinders	4	7
	4-cylinders	3	
Yanmar	6-cylinders	1	6
	4-cylinders	5	
Iveco	6-cylinders	5	6
	4-cylinders	1	
Sisu	6-cylinders	4	4
Cummins	6-cylinders	3	3
Ford	6-cylinders	2	2
Thornycraft Leyland	6-cylinders	1	1
Kubota	2-cylinders	1	1
Solé	4-cylinders	1	1
VW	4-cylinders	1	1
Lombardini	4-cylinders	1	1

Table 7.- Engine make, model and quantity used.

Illustration 16.- Volvo Penta, 12L 6 Cylinder

2.4. CONCLUSION

Now that the facts and properties of the biodiesel are known and put in to perspective in the research part, it is time to take a look at what these facts and properties really mean to the fishing boats situation and what the problems are that might occur. This means that there has to be found out how the biodiesel behaves and which of these behaviours really influence the usage of biodiesel on fishing boats.

3. SCOPE

3.1. LINK BETWEEN RESEARCH AND PROBLEMS

The research has been separate in three different big topics:

- Energy in Finland
- Biodiesel
- Fishing industry in Finland

Each topic gave us several information about our future solutions. The Energy and Fishing industry research gave us statistics and practical information and the biodiesel part is more about chemical properties of our fuel. The team first collected data about the consumption of energy in Finland, then more information about the fishing industry, how is this sector doing right now, what are the issues, what is the fishermen's behaviour nowadays.

With all these information, we know how fishermen are expecting the solution and which price range they are ready to accept.

3.2. DEFINE THE PROBLEMS

As it is known, biodiesel has many advantages, however some problems derived from the usage of this bio fuel can cause damaged to the engine system.

First of all, pure biodiesel is a remarkable **effective solvent**, it has excellent cleaning properties, it will dissolve accumulated sediments left by the usage of conventional diesel in the fuel system. This is the principal reason why the filters should be changed frequently. The fishermen that have been interviewed for the purpose of this report have shown a high concern about this topic. The dirt carried by the biodiesel can collapse the pipes and the engine system could be ruined in the middle of the sea, so all the engine system and the storage tank have to be well cleaned before using B100. (21)

One of the biggest problems that both consumers and producers must face is using bio diesel in **cold climates**, especially with non-blended bio fuel (B100), because it freezes faster than most petro diesel. It will always be important to heat the fuel system and the bio diesel above 10ºC, otherwise the biofuel viscosity will reach an unpleasant high value, causing damage to tanks, pipes, pumps and of course the engine. (41) (13) (21).
Some additives, nº1 diesel (kerosene) and pour point depressants can work on mixtures of B20 making a lower flow temperature. On the other hand no additives have been shown to be effective on B100. (42)

It is also important to know the basics of storage. There are several materials that can oxidize the fuel, forming sediments and fuel degradation like, copper, brass, zinc, lead, and tin. They should be replaced with aluminum or steel. The bio diesel is able to dissolve plastic materials, but not synthetic materials such as nylon, teflon or viton. (39) (13)

The products from the oxidation process can cause damage and corrosion to the metal components of the system, also components made by rubber or elastomers will be damaged. (21) (15)

Other problem detected by suppliers and consumers of B100 is the **water contamination** both in the storage tank and in the engine system. The ethanol inside the bio diesel is able to absorb water from atmospheric moisture. (43)

3.3. EXPLAIN THE BIGGEST ISSUES

Let's start with one of the biggest problems that fishermen must confront: **water contamination**. As it has been said before, the ethanol can absorb water from atmospheric moisture, but also H_2O can show up as a residual of the process of transesterification, finally the water can appear from the condensation in the storage tank. The bio diesel acts as an emulsifier due to its hydroscopic power, so this bio fuel can absorb up to 40 times more water than normal diesel. (43) (44)

There are several problems related with this contamination:

- If the water content exceeds 60 ppm there is a possibility of **microbial life** in the bio fuel. FAME bio diesels (fatty acid methyl ester) are more susceptible of harboring fungi, yeasts and bacteria. The reproduction of this life form is by duplication in favorable conditions, so they have a exponential growth with available food and sustainable temperature. (45)

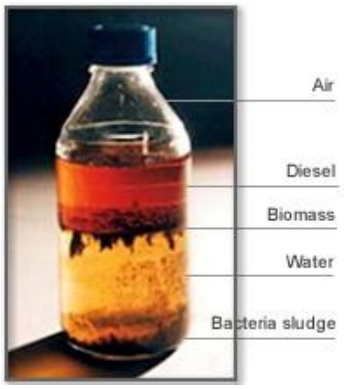


Illustration 17.- Microbial life in biodiesel (44)

- Also water might normally give the fuel **lower lubricity** properties, reducing the life of moving parts. (13) It will cause **corrosion** on metals like aluminum and steel, clogging fuel lines and filter elements, causing power loss and engine breakdowns.
- H_2O is able to diminish the **heat of combustion**, translated in a harder starting with less power and more smoke. (43)
- As it is known the water can freeze at temperatures close to 0°C forming **ice crystals** speeding up the gelling of the bio diesel. (43)

Another big issue regarding fishermen's boat engines is the problem of viscous biodiesel at low temperatures. The performance of bio diesel in cold temperatures really depends on the origin, properties of the bio fuel and the raw material used. The viscosity is considered as a quite important property because it influences the atomization of the fuel.

When the temperature of the oil decreases, it begins the conformation and growth of crystals (46). In the oil composition it can be found, in low concentration, high weight molecular substances such as saturated monoglycerides, these particles form waxes, which shows a bad performing in cold temperatures, affecting the filterability (47).

3.4.GOALS + EXPECTED RESULT

The ultimate goal for the team is to find a solution which conciliate the solving of all our issues, indeed, the solution has to be cheap, be adaptable, and prevent water contamination and viscosity issues. It also has to be perfectly reliable because it is an on-board system from which the boat is fully dependent of.

There are a lot of possible solutions and the better one will be the one which will respond to all the needs. It is hoped that the fishermen will accept the solution and be ready to change their system. In the end the solution that will be given will be composed of 3D model, economic study and a booklet.

- The 3D model will be necessary to start the realisation of a prototype in the future, it also offer a better view of the system and allows the realisation of structural and strength calculations to determine with precisions the dimensions needed.

Illustration 18.-3D model of a factory (solidworks.com)

- The economic study is essential to determine the profitability of the system and the time before return on investment in order to motivate the future owner of the system.

Illustration 19.-Economic study logo (tkworldwide.com)

- The Booklet will be helpful for the user, inside, he will find a notice which explain how does the system works. The booklet will be printed separately and will be added as an appendix in the report.
-

Illustration 20.-Fibiod booklet (by R Dupaty, original from craftorstudio.com)

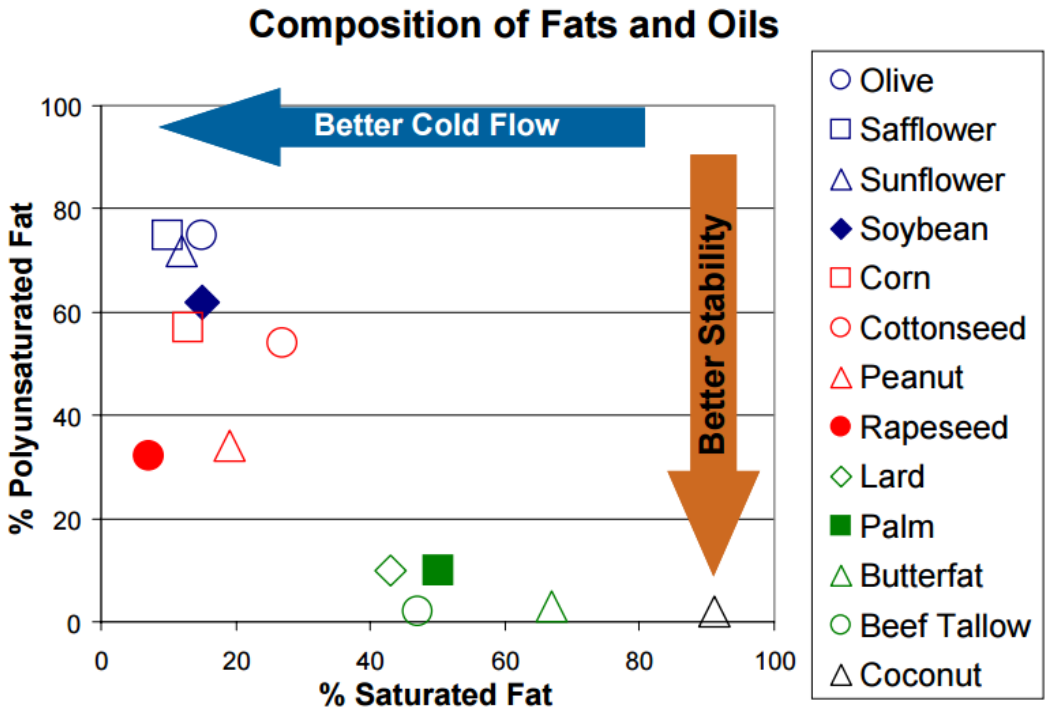
The team will also provide a complete report and a presentation about all the project which explains how the work has been done.

4. SOLUTIONS

4.1. EXISTING SOLUTIONS

4.1.1. WITH GOOD COLD FLOW PROPERTIES.

Biodiesel consists out of two different oil molecules, saturated and unsaturated molecules. Saturated molecules have a higher cloud point, this means that saturated molecules will crystallize at a higher temperature. The unsaturated molecules on the other hand will crystallize at a low temperature, they have a low cloud point.



Graph 17.- Composition of fats and oils (17)

Research has shown that by separating the saturated from the unsaturated molecules there will remain a bio fuel that can be used in cold temperatures. The process of separating the two molecules is called "fractionation". However this method is not recommended when the bio fuel is made out of recycled animal fats and oils. Animal fats and oils contain a high amount of saturated molecules, therefore it will crystallize at a higher temperature then vegetable oils. However this process is being used for biodiesel from vegetable oils, and so far is looking successfully. (48)

4.1.2. BIODIESEL HEATING SYSTEMS

To prevent biodiesel from gelling in different conditions and machines there are some solutions on the market to prevent this. Here below there are shown some products that could help biodiesel to stay in liquid form.

Universal Submergible Heater

This is a universal submergible heating spiral being able to be placed in any kind of container. An example is the "1000 watt Bucket/Drum Heater" supplied by Utah Biodiesel Supply for $45,95.

Illustration 21.-Heating Spiral (49)

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Universal Heating Straps

These are straps with heating spirals implanted which you can strap around the outside of a tank or container. An example are "Band Pre heaters" supplied by Home Biodiesel Supplies for $295.

Illustration 22.- Band Pre-Heaters (50)

In-tank Heater

This a heater spiral that is fixed inside the tank that can be used by electricity or cooling water from the engine. Examples are "Biodiesel Fuel Tank Heaters" supplied by Reliance Energy Resources Llc. ranging from $339,95 to $439,95.

Illustration 23.- In Tank Heaters (51)

4.2.CHOSEN METHODS

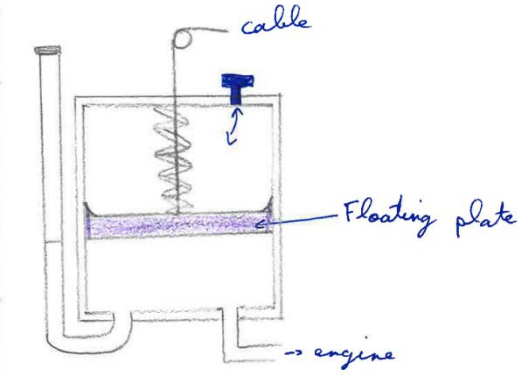
The two big problems that need to be solved are the water contamination and of course the fuel heating. For both problems the team will first generate some quick designs by using the brainstorm method. When there are enough solutions the most promising will be chosen and expanded into a detailed concept.

4.3. NUMERATE SOLUTIONS

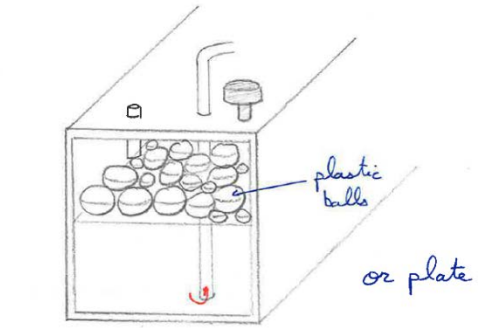
4.3.1. QUICK IDEAS

Before finding the final solution the team has to brainstorm exploring all the technologies that could be used. Different solutions have been compared to avoid the water contamination caused by the water which vaporize from the fuel.

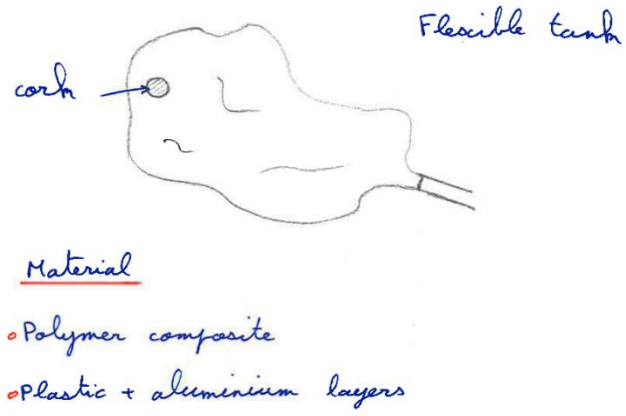
Here are some sketches about some possible solutions:



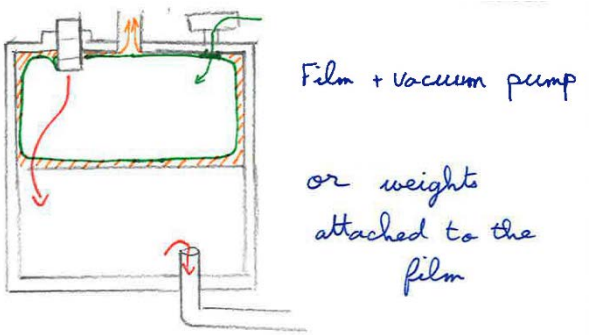
Here, a floating plate stay above the fuel to create a real wall that prevent the vaporisation. A spring maintain the plate in contact with the fuel. Then is order to be able to fulfil the tank, a cable help to bring the plate at the top of the tank.



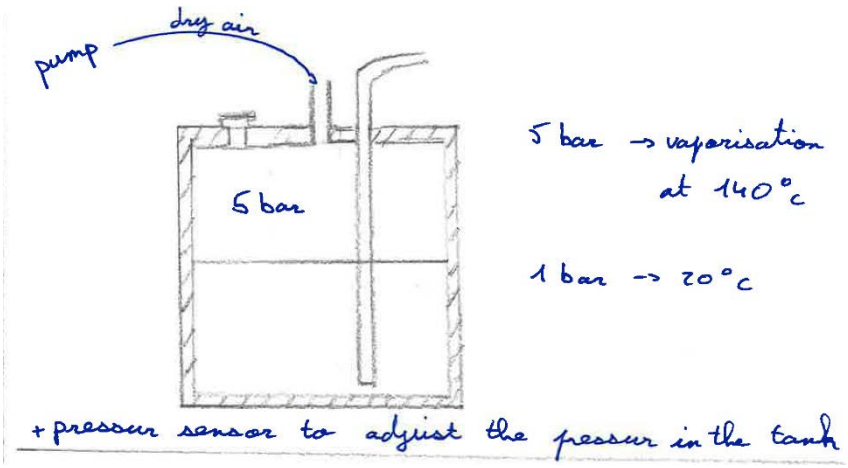
This solution uses the same principle than the previous one. The goal is to create a fence against the vaporisation. Following a project made by the city of Los Angeles in a reservoir, plastic balls are inserted in the tank, and will stay at the surface of the fuel.



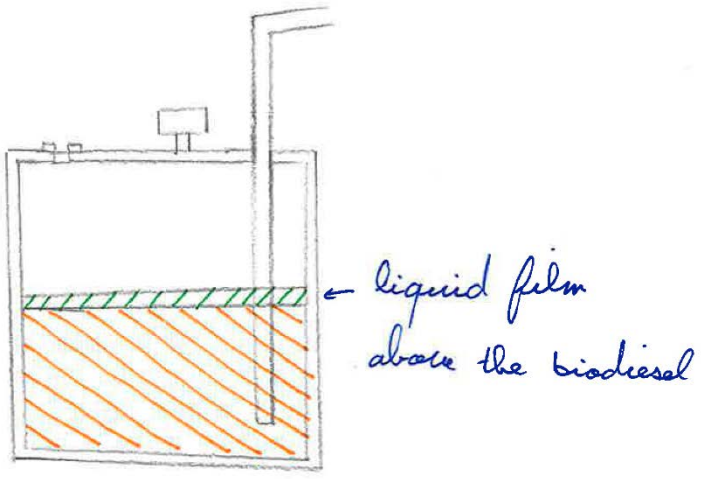
A flexible tank would be a really good solution. In fact the volume of the tank will always stay the same as the volume of fuel so there is no empty space where steam can go. The problem with this solution is that adding a warming system inside is not simple.



A bag made with a plastic film will fit on all the surfaces in order to create a wall that prevent the vaporisation. A vacuum pump can help the bag to take the space.



An air pump pressurize the empty space in the tank. The consequence is that the water will need a higher temperature to vaporise. And it will also condensate much more easily which will keep a constant concentration of water in the fuel.



A liquid film can be used to create the wall. For example, a film of oil can prevent the vaporisation in a better way that all the other solution. For this reason the team decided to make some experiments in the laboratory to find a fluid that could stay above the fuel. These experiments can be found further on in the report.

4.3.2. DETAILED SOLUTIONS FOR WATER CONTAMINATION

After the team did some individual and collective brainstorms several ideas were created. The three ideas that seemed most efficient and viable were chosen. The next chapter will show the results and summarize both positive and negative points of these solutions.

4.3.2.1. FUEL BLADDER

As the fuel bladder could be used a flexible bag that contain the corrosive biodiesel without having the problem of water condensation and therefore no microbial growing. It has a Nylon core which is double thick coated for wear resistance. The storage bag could be used outside of the boat but it is useless in winter time as the biodiesel will freeze instantly. To combat the frozen temperatures, the flexible bag, made by a stronger material (nitrile rubber) could be located under water, where the temperatures will be more moderate. In spite of the temperature advantage, this solution has been rejected for several reasons, the most important one is the high probability of breaking the bag: rocs, animals and the winter ice can cause damage to the strong nitrile rubber. As it can be seen in the illustration (24) and (25) the flexible bag fits to the amount of bio fuel that has in its interior, so there will be no air pockets thereby, preventing water condensation.

Illustration 24.- Empty flexible bag (52)

Illustration 25.- Full flexible bag (52)

One of the best advantages of using the flexible bag of nylon or nitrile rubber is the easy handling of it. It could be storage in any part of the boat and it solves the problem of the water contamination. On the other hand, the easy freezing of biodiesel can make that the flexible bag stop working as it should, swelling and emptying whenever it’s needed it.

In the next illustration (26) it can be seen how the flexible bag works with warm biodiesel in its interior. As it has been already explained, if the temperature of the bio fuel reach less than 10 °C, the viscosity will increase, and the bag will not work as a "flexible" container.

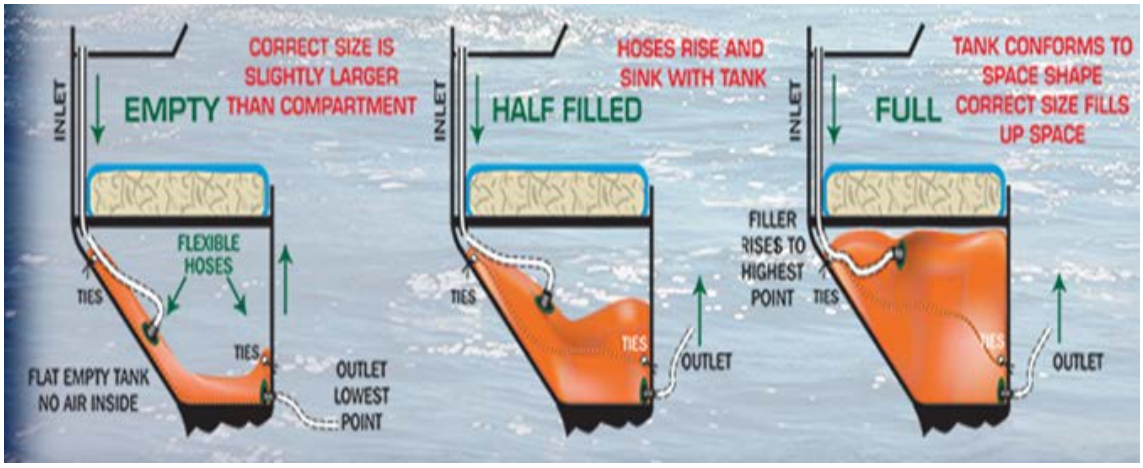


Illustration 26.- Flexible bag's shape; These flexible bags are made of synthetic materials as nylon, but the most powerful material to storage the destructive biodiesel is nitrile rubber. (52)

4.3.2.2. PRESSURIZED BAG

This solution uses two different tanks, the first one for biodiesel and the second one for normal diesel. It is necessary to keep a little tank of normal diesel in order to use it to warm the engine. The solution uses a plastic bag in order to fill all the empty space and prevent the water from vaporizing in two ways:

- If there is no space then the steam cannot appear.
- As the bag is pressurized, it will touch the surface of the liquid and create a wall against vaporisation.

The first concept of this solution (illustration 27) shows that the system is composed of a pump linked to an air filter which will remove moist from the air.

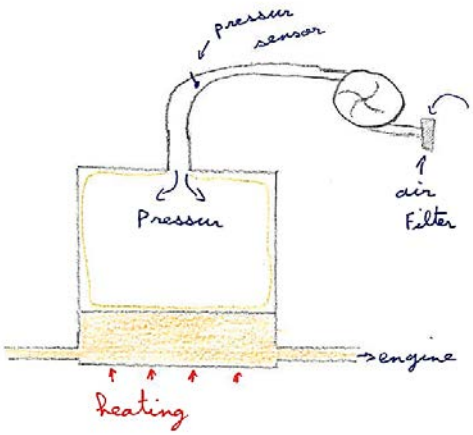


Illustration 27.- Sketch of the pressurized bag solution

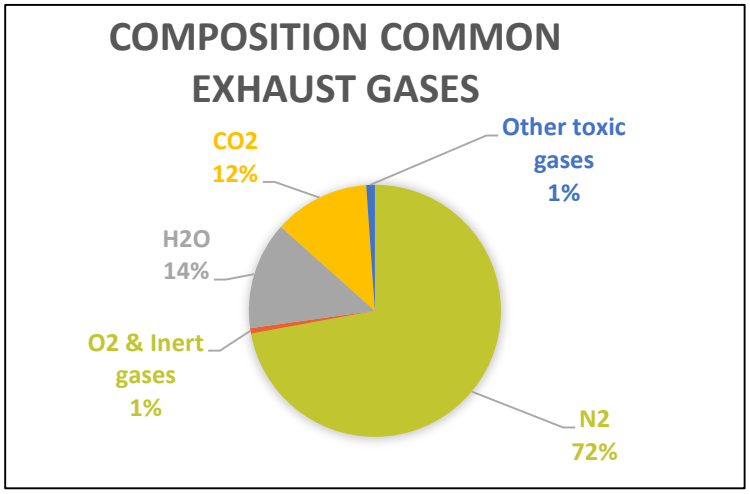
When the engine is running, the fuel level will decrease, so the pump will also be used to correct the difference in volume between the bag and the empty space.

The target is to maintain the pressure in the bag between 2 and 5 bar to be sure that the surface of the bag will fit inside the tank and thereby avoid the vaporisation of the water in the biodiesel.

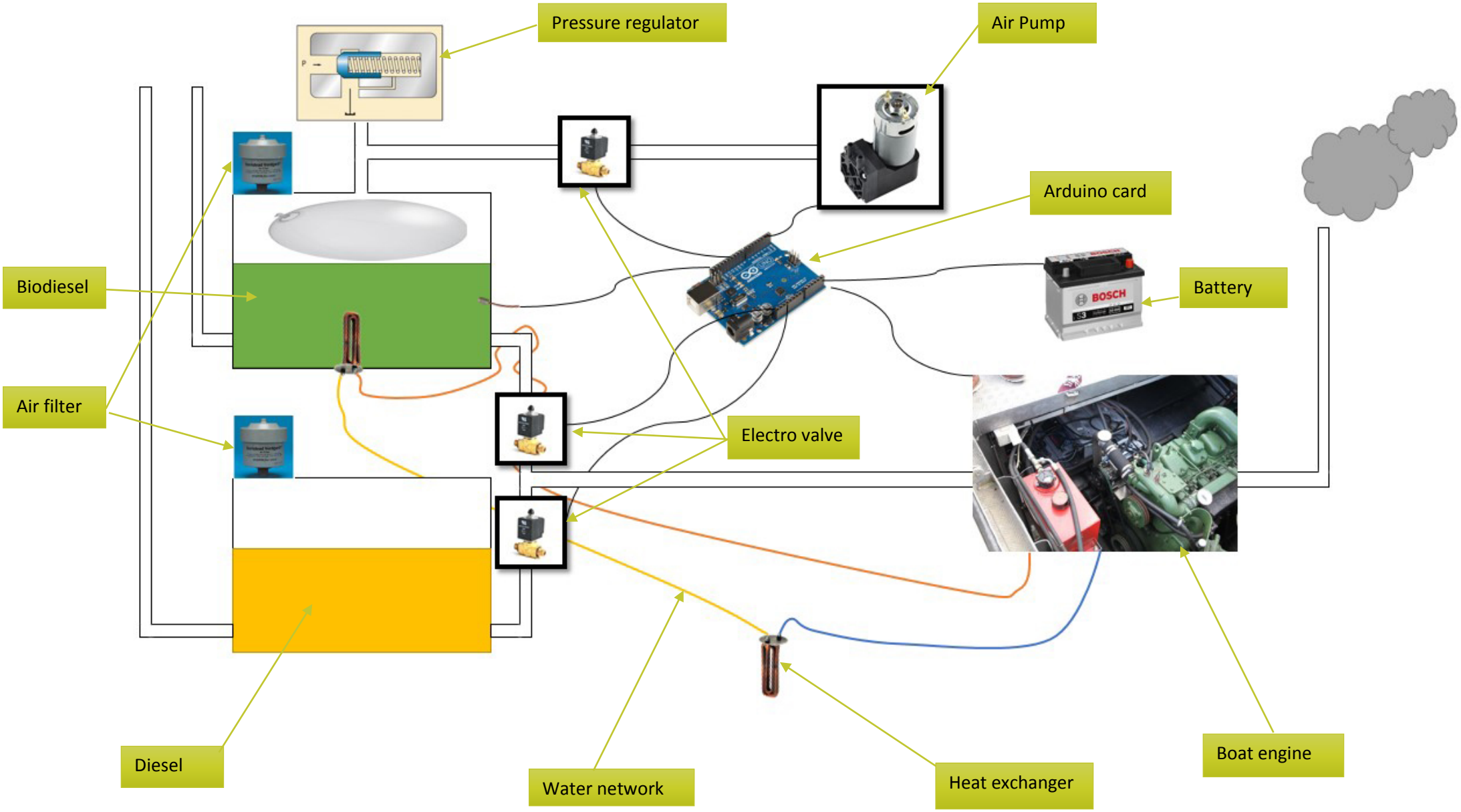
Another solution that uses the exhaust gases from the engine has been studied. But after some research it showed that these gases contain about 14% (graph 18) of moist air which means that if these gases go in the bag, there is a risk of condensation, which can create mold and deteriorate the bag prematurely. Furthermore, if an air filter is used in order to remove the water, it will wear out quickly. Using the exhaust gases seems to be a bad idea even though if it could work without a pump.

In the end this solution will use the concept of the first concept but with more devices in order to be realistic. To be effective the solution has to be reliable, cheap and has to have a long life cycle. That is why it is necessary to use reliable components,*- which will work well in a boat.

The following schema illustrates how the system works, it is explained in the following pages, in order to be easier to understand it is recommended to have a quick look at the schema first and then go to the explanations that are written after.



Graph 18.- Composition of exhaust gases: www.ngk.de


Pressure regulator
Air Pump
Arduino card
Biodiesel
Battery
Air filter
Electro valve
Diesel
Water network
Heat exchanger
Boat engine

According to the schema (see page 56) the solution is composed by several elements summarized below.

- **The Arduino Card**

The Arduino card (illustration 28) is the brain of the system. This card is coded with a program, which will create a sequence to follow (see above). When the program is ready, it has to be uploaded to the card which will then control all the other devices (sensors, actuators). This type of card is really reliable, in the worst case scenarios the Arduino will stops working. A complete emergency procedure (see page 101) will be applied in order to avoid an engine failure.

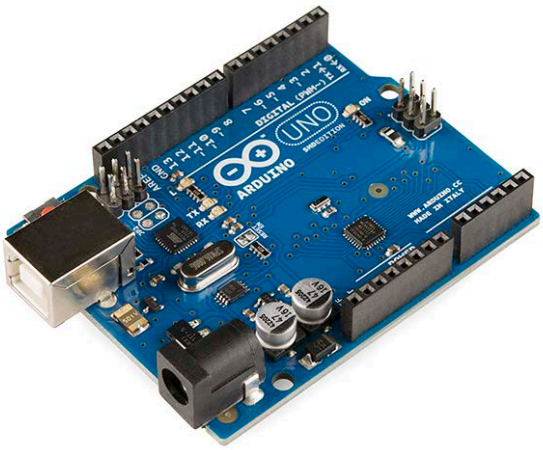


Illustration 28.-Arduino UNO card: www.arduino.com

- **The electro valve:**

is the electro valve is a simple device connected to the Arduino card. When the card sends a signal, the valve (illustration 29) will switch its position (open/close) there is no intermediate position. The position only changes when a command comes from the card which means that in case of power failure, the boat engine will still have fuel supply from the last tank used. The electro valve can also be switched manually in case of emergency.

Illustration 29.-Elecrovalve www.espressotec.com

- **The pressure regulator:**

This fully mechanic part is essential to prevent the plastic bag from exploding or the air pump from breaking because of increased pressure. The system is simple, the air has to push through a metal part linked to a spring. If the pressure is high enough to create a force which can move the spring then the blue part will move, allowing the air to escape which will decrease the pressure. The strength of the spring can be set using a screw in order to choose the maximum pressure allowed in the bag.

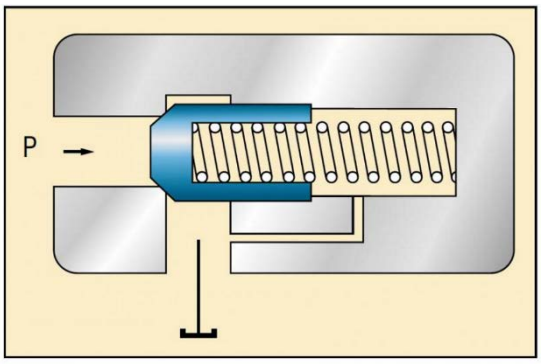


Illustration 30.- Pressure regulator

- **The air pump**

As the level of biofuel decreases, it is necessary to maintain a constant pressure in the bag to prevent vaporisation. That is why the air pump is essential. When the biofuel is used, the air pump will constantly send pressurized air in the bag and the excess pressure will be regulated by the pressure regulator.
Using the Arduino intelligently can save energy. When the pump is using a lot of force, the amount of electrical power that it consumes will increase. According to that fact the Arduino can stop the pump when the power increases because it means that there is enough pressure. It will start again after a short while. It is also possible to use a sensor.

Illustration 31.-12V air pump www.everychina.com

- **The air filter**

Illustration 32.-Barnstead industrial air filter

An air filter is a very common device that will simply remove the water from the air that flows through it. It has to be changed after several months of utilisation because the process, which removes the water uses a chemical reaction. Three filters are used; one in the diesel tank, one in the biodiesel tank and one for the air pump. The filter for the diesel works in both directions but the filter for the biodiesel and at the entrance of the air pump only works in one direction.

- **The heat exchanger**

Heat exchange can be realised with a lot of different systems, they will be described later in the report. Its role is to transfer the heat from the engine to the biodiesel tank by using the cooling water. Then it needs to cool down this water to use it again in the engine. This all happens in a closed cycle.

- **The plastic bag**

The plastic bag is actually the most important part of this solution. This bag will be the only fence against the water vaporisation. As it will be permanently in contact with the biodiesel the bag has to be resistant to the heat, the chemical attack and wear. In order to find a flexible plastic which can handle these extremes conditions, a multi-layer film has been chosen to create the bag, this film is composed of multiple layers.

- The first layer of Polypropylene (PP) will give a strong heat and shock resistance to the film
- The middle layer is made of Polyethylene (PE), an interesting plastic which makes the film fully impervious and resistant against chemical attacks and shocks.
- The last layer is in contact with the biodiesel and is made of composite polymers that are mainly composed of fibers of Polyethylene terephthalate and nylon which has a really strong chemic resistance.

Now that all the parts have been described, it is the time to come back to the brain of the system: the Arduino card. It is programmed with a simple step-by-step pattern which follows these orders:

```
Engine On:
        If: t° biodiesel > 20°c: open air valve + start air pump
        Else: Switch to diesel + open air valve + start air pump
Biodiesel temperature: 20°c
        Switch to biodiesel
Engine off:
        Switch to diesel for 10 sec
        turn off the engine + close the air valve + turn off the pump
```

Sequence that the Arduino card will follow.

When the fisherman turns the key, the Arduino will start the engine. Then it will check if the biodiesel is ready for utilisation, this means that its temperature is higher than 20°c. In this case, the Arduino will switch to biodiesel and pressurise the bag. In the other case it will continue to use normal diesel but also pressurise the bag because the pressure will change as long as the biodiesel will warm up.

When the biodiesel reaches 20°c, the Arduino will switch the fuel. When the fisherman turns the key to turn off the engine, the Arduino will switch to normal diesel during 10 seconds before turning off the engine in order to clean all the circuits from biodiesel which could be too viscous at the next utilisation.

The real Arduino programme can be found in the Annex (Appendix 1)

With this program the idea is to test the card directly by using DEL instead of valves, engines, pump, etc. in order to check that everything works normally.

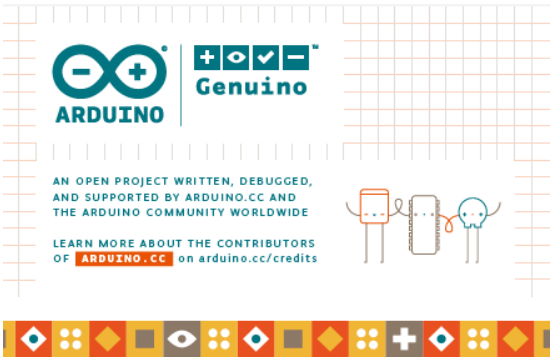


Illustration 33.- Arduino software www.arduino.com

Security and maintenance

In case the system fails a security process has been designed. The electro valves have two different securities:

- In case of power failure, the Arduino will stop sending current to the valves so the biodiesel valve will automatically close and the diesel valve will open. This is made in order to be sure that the pipes will be cleaned of biodiesel when the fisherman is heading back to the harbour.
- If the diesel tank is not far from empty, then it is possible to manually switch the electro valves with a lever, so the fisherman can always choose the fuel.

It is also always possible to manually switch the air pump on and off with a switch. So indeed the entire system can be used manually without the Arduino, which only serves to simplify the job for the fisherman.

About maintenance, the sensitive thing to take care of will be the air filters. They will have to be changed regularly in order to prevent any water contamination. The plastic bag will probably have to be changed after a long period of time (about 5-10 years). The electrical circuit will be isolated in pipes so its life time won't be a problem. As with all systems that use biodiesel, it will be necessary to fully clean the tank after a long period of utilisation.

The system is not complete and ready to work, but it gives us a good idea of a solution that could prevent the water vaporisation.

Economic study

The system has a primary cost and then a maintenance cost. All the different parts have their own life time and will have to be replaced after a certain period of utilisation.

So in one sense, the fisherman will have to be the technician of his own boat otherwise he can also contact Fibiod to get a complete check of the fuel system. In this study, the warming system will not be evaluated because the solution only concerns the water contamination issue.

Part	Average Price	Source
Air pump	12 €	http://www.robotshop.com/
Plastic film	10€/m²	Average from different companies
Electro valve	70 €	http://www.conrad.fr/
Arduino Uno	20 €	http://boutique.semageek.com/
Cables	0.3€/m	http://www.conrad.fr/
Pressure limiter	40 €	https://plomberie.fr/
Air filter	25 €	http://www.tooldom.com/

Table 8.- Price of the different elements

According to the fact that we will use 3m² of plastic and around 50m of cables. The total price is estimated to be around €450. A 100 litres diesel tank costs about €300 which gives us the final price of €750 for the complete solution without the warming system.

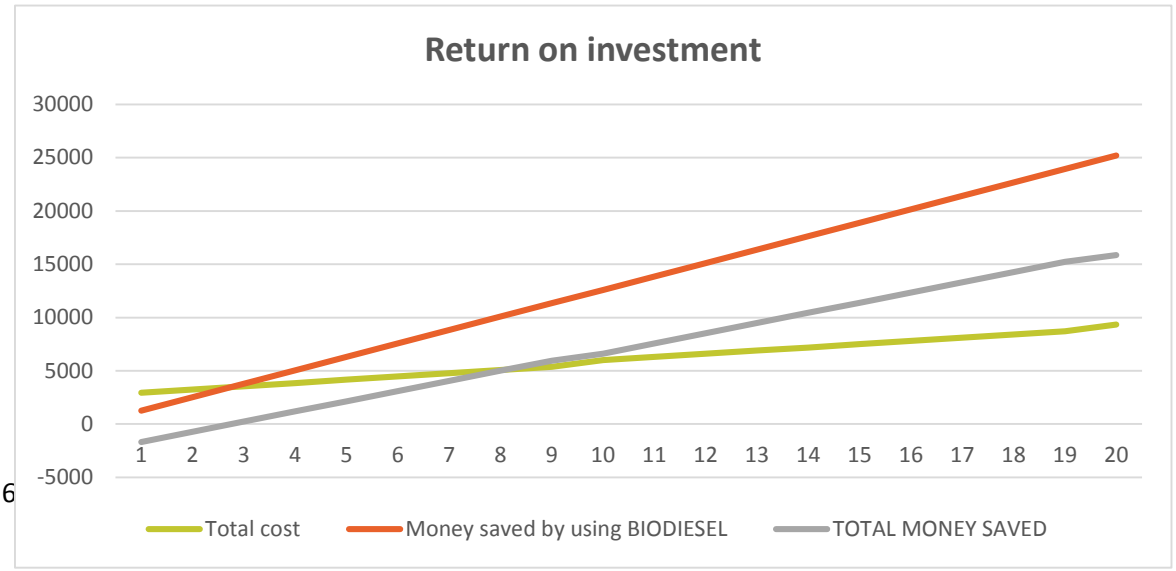
Maintenances data	Replaced after
Air pump	10 years
Plastic film	5 years
Electro valve	10 years
Arduino Uno	10 years
Cables	20 years
Pressure limiter	10 years
Air filter	Around 3 months

Table 9.- Life of the components

In order to prevent any issues with the system, the fisherman will have to regularly check all of the components to verify that everything is working normally.

(These data are not contractual and might change)

As the solution does not take in consideration the price of the warming system, the time before the return on investment might change. On the graph bellow (graph 19) it can be seen the estimation of the price of the warming system is about 2000€, according to the grey line, the return on investment will happen at the beginning of the third year.



Graph 19.- Return on investment

Heating system price	Return on investment
500	2nd year
1000	2nd year
3000	4th year
5000	6th year

Table 10.- Return on investment

The table 10 shows the time before return on investment according to different initial prices for the heating system.

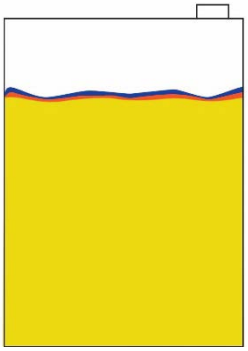
To conclude, this solutions looks interesting. The price is not too expensive but it always depends on the fisherman's wishes. The return on investment can be fast and after 10 years, several thousand eros could be saved. Furthermore, all the components are easy to find, to replace and are reliable.

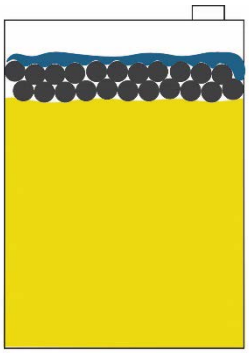
4.3.2.3. PROTECTIVE LAYER ON TOP OF FUEL

To prevent the air from contaminating the biodiesel a layer or barrier can be created on top of the fuel in the tank to separate both. Different methods can be used to create this barrier. Important issues to take in account is that the water on top of the layer should be prevented from contaminating the water when refilling the tank. Further on the fishermen use different types of barriers which vary in size and shape.

- **Oil**

Some experiments with oil were conducted to try and create a barrier. The big advantage of this method is that it would work in any tank, no matter the shape. When filling the tank the biodiesel would penetrate the layer that would automatically close again over the biodiesel. The problem that arose was that the density of the biodiesel was lower than the tested oils. This resulted in a layer on the bottom of the tank instead of on the top. More about this experiment can be found on the next pages.

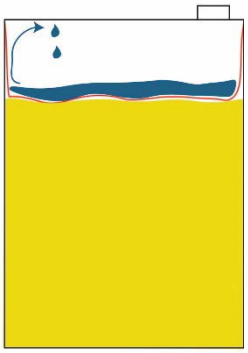




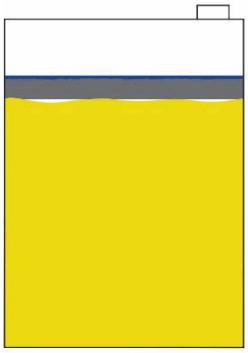
- **Plastic balls**

This method uses plastic balls to make a barrier. The balls can be inserted through the filling hole, this means that this method can be applied for all thanks, no matter their size or shape. The problem is that water will gather on top of the plastic balls. Rough sea or refilling the tank may cause the large amount of water gathered on top to mix with the biodiesel and impact the viscosity.

- **Film**



By applying a small film in the tank, the moist air and the fuel will be separated. In order to prevent moisture from piling up on top of the layer, a fabric that absorbs water can be placed inside the tank. This material changes its color when it needs to be replaced. The edges of the film will have to stick to the tank perfectly or the condensation that runs down the sides of the tank will contaminate the water. The problem with this idea is that the film has to fit the size and shape of the tank. Since most tanks have different shape this would result in a solution that will have to be personalized for each buyer. This increases the installation time and cost.



- **Foam**

This idea uses a synthetic foam that can be sprayed on top of the oil to form a barricade. A conical shaped tank might be a problem for this solution since the hardened foam won't be able to follow the fuel level. The problem here is that the search for a foam with the right properties came up negative.

Experiments with oil

In order to find solutions in order to create a layer of fluid above the biodiesel, it was necessary to do experimentations with different fluids to see first if it mix or if it create layers and then if the layer of biodiesel is under the other one.

The expected result was to find something which could create a layer above the biodiesel without mixing with it. This layer is necessary in order to prevent the vaporisation of the water already present in the biodiesel.

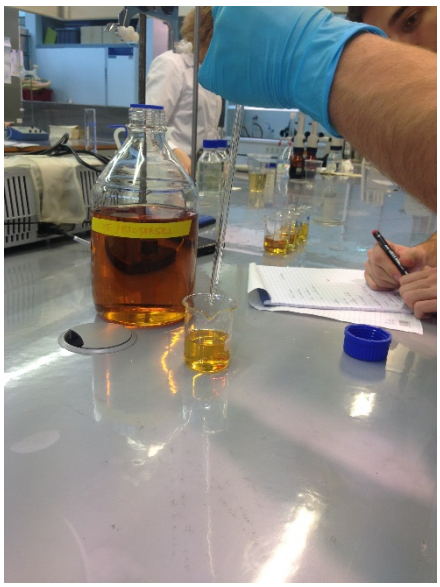


Illustration 34.- Experiments in the laboratory

Different experiments have been tried:

First liquid (density)	Second liquid (density)	Result
Biodiesel (0.87 g/mL)	Acetone (0.78 g/mL)	Mix
	Almond oil	2 layers but the almond oil's one is under
	Isopropyl alcohol (0.78 g/mL)	Mix
	Petroleumbenzin reinst (0.65 g/mL)	Mix

Table 11.- Experiments Results

Illustration 36.- Different results

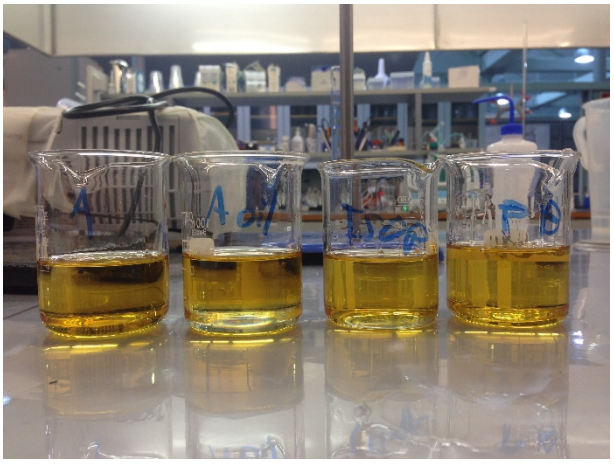


Illustration 35.- Different results and layers

The result was not the one expected and none of these product had the hoped properties. The utilisation of a fluid layer seems hard to develop as the team did not have enough chemical knowledge. In order to reach the same goal, a solution using a physical object like a floating plate looks feasible.

4.3.2.4. TANK DRYER

Another solution for the water contamination is the super absorbent polymers. It will act as a tank dryer, removing all water content inside the biodiesel tank.

Illustration 37.- Potassium based super absorbent polymer (76)

Super absorbent polymer crystals are formed by the polymerization of different chemist particles as poly(vinyl alcohol) PVA or poly(ethylene oxide) PEO, all of them are hydrophilic and have high affinity for water. These crystals are able to absorb and hold huge volumes of water. They are well known in the textile industry, as it is the mainly product use in the baby diapers. (53)

It is important to understand why those crystals don't dissolve in water or why they stop taking water at some point. Cross-links connecting polymer chains form a three-dimensional network, this geometry is the one that prevents the polymer swelling to infinity or either dissolving (54). The gain of water causes a decrease in the entropy of the chains (illustration 38).

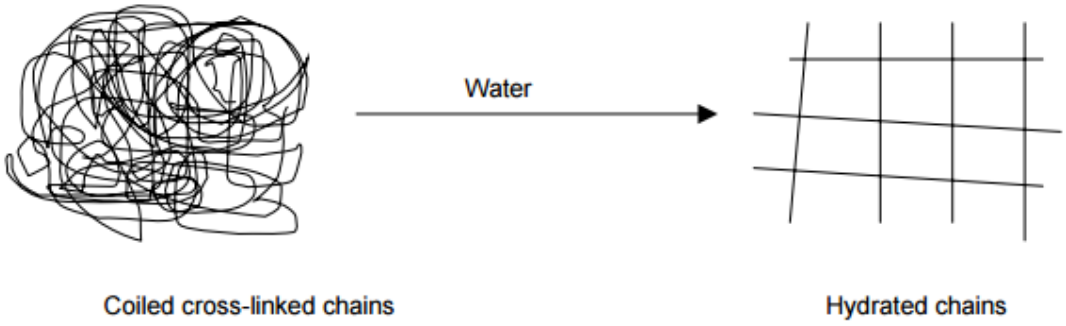


Illustration 38.- Behaviour of the super absorbent polymers. (53)

There are some commercial solutions to use super absorbent polymers as a tank dryer to remove the water from the biodiesel tank. It is presented in the head 5.2 Final solution concept (page 82)

4.3.3. DETAILED SOLUTIONS FOR FUEL HEATING

There were two general approaches to solve the heating problem. The first one uses only electricity to heat the fuel system. The second option uses electricity to start-up and once the engine is warm enough, the system will be heated with the cooling water from the engine.

There are three main components that must be heated. The most important one is of course the fuel tank. For the fuel line, there are two possibilities. Either there will be a system that flushes the engine with normal diesel after the fisherman turns of the engine. In this case there will be no need to heat the fuel lines since the diesel won't gel. If the system doesn't get flushed, the lines will need to be heated. The third component is the fuel filter. When the biodiesel gets cold the gel will clog the filter more easily. It's crucial for the durability of the filter that only warm diesel flows through.

4.3.3.1. ELECTRICAL HEATING

The advantage of using only electricity is that the circuit can start even if the engine is not yet running. An extra battery might have to be installed to provide enough energy.

IN-LINE HEATING SYSTEM

The in-line heaters can also be called circulation heaters. These kinds of heaters are optimal for processing fluids that requires halfway heating while maintaining a flow rate. Instead of taking heat from another source like heat exchangers, the in-line heater transfers the heat coming from electrical power to the fluid. The benefits for using this method is the efficient heating transfer, easiness to install and to maintain. Regulating and controlling the temperature can be done with steam and water processing. The fluids viscosity can be maintained with these systems. If the fluids viscosity is unsuitable, it will cause problems in the engine.

To avoid these problems the in-line heating system keeps the temperature and the viscosity unchanged. It even keeps the medium at a desirable steady flow rate. To control the flow rate of the heater the wattage can be manipulated and regulated to keep up the desired temperature.

The in-line heating system can consist of a pump and electrical heating cables around the fuel lines. There can of course be many different heating solutions, eg. steam pipes around the fuel lines using exhaust gas-heat. (Wattco, 2015)

KILOWATTS	STANDARD VOLTAGES 1 PHASE ONLY	WATT DENSITY (W/cm²) (W/in.²)		WITHOUT THERMOSTAT CAT. No.	WITH THERMOSTAT 10 - 120°C (50 - 250°F) CAT. No.	NET WT. (KG)
TYPE MSX - COPPER SHEATH (BRASS PLUG & VESSEL WITH 1" NPT CONNECTIONS						
1.0	120, 208, 240	12.4	80	MSX110B	MSX110BT	13.2 (6)
1.5	"	12.4	80	MSX115B	MSX115BT	13.2 (6)
2.0	"	12.4	80	MSX120B	MSX120BT	13.2 (6)
3.0	208, 240	12.4	80	MSX130B	MSX130BT	13.2 (6)
TYPE MWHI - INCOLOY SHEATH (STEEL PLUG & VESSEL WITH 1 1/4" NPT CONNECTIONS						
0.6	120, 208, 240	2.3	15	MWHI206EO	MWHI206EOT	17.6 (8)
1.0	"	3.9	25	MWHI210EO	MWHI210EOT	17.6 (8)

Table 12.- Technical specs over the miniature circulation heaters by Wattco

As seen from the previous table (table 12), a possible heating solution from Wattco is the 0.6 kW miniature circulation heater. The standard voltages for this heater are 120V, 208V and 240V so a voltage inverter is needed. The fuel lines are connected to the in-line heater and it warms up the fuel, eg. Before the filter, the installation place can be freely chosen. With the following equation we calculate the operational time of the heater with engine off: Using a 240 V inverter with a 12 VDC battery and the continuous power demand of 600W the run-time of the battery is 600 W / 12 V = 50A * 1.1 = 55 A (90 % effectivity of the inverter) 100 Ah / 55 A ~2h of continuous usage. Of-course the battery will recharge in both cases when the motor and generator is running. There is also the possibility to buy an extra battery to keep it separate from the engines battery, extending the heating time. (Mercury, 2014)

Another solution in using the in-line heating system could be an electrical fuel heater called ATG diesel-therm produced by a German company named Alternative Technology Group, see figure1. This system prevents the filter's holes from clogging up at low temperatures by warming the fuel with the help of a small heater. This heater is mounted in front of the filter and prevents problems associated with cold fuel or the loss of power because of a clogged fuel filter. The heating is controlled by an on/off-switch by the driver in the cabin. An indication light is glowing in the cabin when the heating system is activated and the temperature is automatically regulated by a thermostat.

The ATG diesel-therm for rubber hoses can be installed in the fuel line with a rubber hose with an inside diameter of 08,10 and 13 mm in front of the filter. Available in either 12 volts or 24 volts, with a power of 200 Watts and 300 Watts respectively. (Alternative Technology Group GmbH, 2011)

Illustration 39.- In-line electrical heating system ATG Diesel-Therm (www.defendertuning.com.au)

Using the 12 V version and a battery with a capacity of about 100 Ah it is possible to calculate how long the battery would last approximately.

I = P / U	->	200 W / 12 V = 16.66 A
C = I * t	->	t = C / I = 100 Ah / 16.66 A = ~6h on constant use

Another option is the in-line heating system developed by Artic Fox. This company specializes in products that help with using fuel in cold climates. They have a large range of products but for this project the in-line heater is the most interesting one. They are available in different lengths varying from 20 cm to 100cm. These products might be a good solution since they are very reliable and easy to install. The downside of in-line heaters is their price tag. If this product is used in the final solution, the total cost will be between 250€ and 700€.

Illustration 40.- In-line heater by Artic Fox (http://www.arctic-fox.com/products/alternative-fuels-in-line-heat-exchangers)

HEATING PAD

Heating pads can be used for many different reasons and the design on the pads depends on the usage. E.g. electrical pads can be used for heating a fuel tank in a vessel and chemical- and hot water heating pads can be used to treat pain in the body. The heating pad that will be used in this report is an electrical heating pad, that's especially made for heating up the fuel tanks in different vehicles.

The electrical heating pads are made of a silicone base with the electrical heating cable inside as can be seen below (illustration 41). The pads are equipped with an adhesive on the back for easy installation on the tank. (Pentair, 2013)

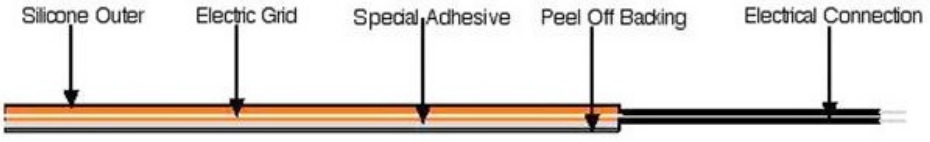


Illustration 41.- How the heating pad look like (www.engineheaters.co.uk)

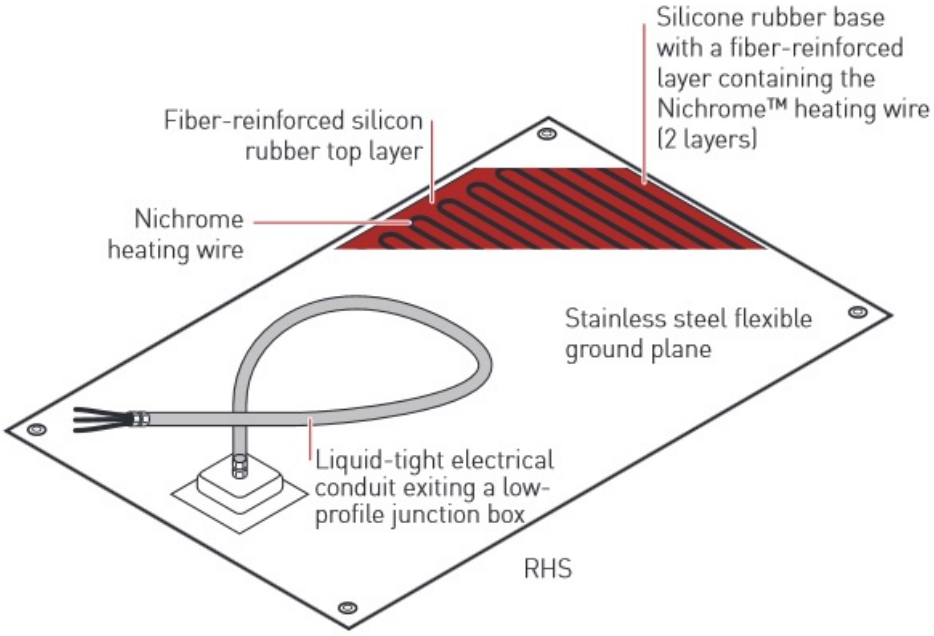


Illustration 42.- Design over Pentairs heating pad Raycham RHS (www.pentairthermal.com)

The electrical heating pad Raychem RHS produced by a company named Pentair are available in two power densities RHS-H for 1.9 W/in2 and RHS-L for 0.6 W/in2. The pads can be used on metal and plastic tanks.

(Pentair, 2013)

The heating pads made by a company called Wolverine Heaters could be used as in this project. The products would be model 16 and model 40C SACE. (Wolverine heaters, 2015)

Illustration 43.- Wolverine heating pad Model 16 (Wolverine heaters, 2015)

Illustration 44.- Wolverine heating pad model 40C SACE (Wolverine heaters, 2015)

Model 16	Model 40C SACE
11,3x9,0 cm	12,7x18,0 cm
250 W	500 W
240V	240 V
77 USD	122 USD

Table 13..- Specifications of wolverine heating pad models

- Model 16

  I = P/U = 250 W / 12 V*1,1 = 18,94 A

  t = C/I = 100 Ah / 18,94 A = 5,28 h on constant use

- Model 40 C SACE

  I = P/U = 500 W / 12 V*1,1 = 37,9 A

  t = C/I = 100 Ah / 18,94 A = 2,65 h on constant use

PTC rubber

PTC rubber is an electronic heating component that is made of polydimethylsiloxane (PDMS) that contains carbon-nanoparticles. This means that the material can conduct/lead electricity current without having any cables. The rubber also works as an insulator, meaning in other words the electrical current can't flow through the material. PTC rubbers other qualities are that they are self-regulating and –limiting.

Self-regulating means that the component keeps a constant temperature without needing regulating electronics and self-limiting means that the heater can never go over a certain temperature in any point and doesn't require overheating protection. These heating elements can be designed to reach a maximum temperature for a given input voltage, thus the name PTC rubber. PTC stands for positive temperature coefficient. The temperature can be set between 0 to 80°C and the power voltage can be anything between 9 to 400 V.

A company named Conflux produces these kind of heaters and their product called flexible small heating foil A12HS, can be a possible solution for heating up the engines fuel lines. The product can be seen in picture below (illustration 45). (ConFlux, 2015)

Length	70 mm
Width	35 mm
Foil thickness	0,35 mm
Temperature	0-80 °C
Voltage	12 V
Price	495 sek ≈ 55 €

Table 14.- Specifications of the small heating foil A12HS

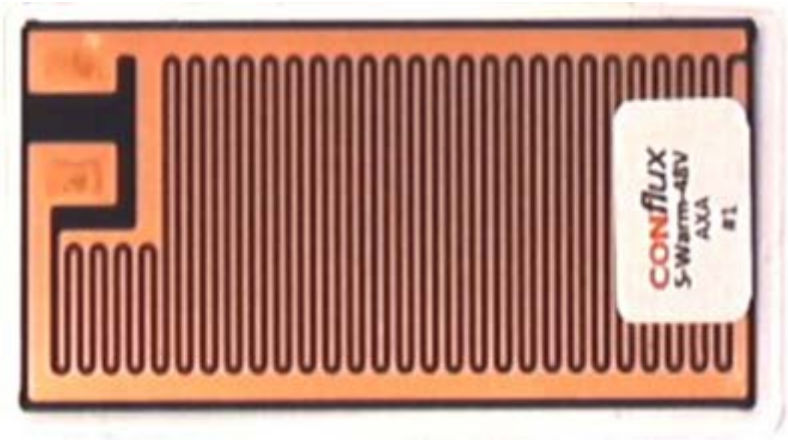


Illustration 45.- Flexible small heating foil A12HS (ConFlux, 2015)

Trace heating

Electrical heat tracing or surface heating is a system used to keep up or rise the temperature in e.g. tanks, pipes, vessels. This type of heating system takes the form of an electrical heating element that can be in contact with the heating object while running. The heated object should be covered in a thermal insulation to prevent heat loss and this also helps the element to maintain the temperature in the tank and pipes. Trace heating is generally used to protect pipes from freezing and to preserve a constant flow temperature in the system. This heating alternative is usually used when the steam trace heating is not desired. (57)

When choosing the right trace heating system there are three alternatives and they are:

- Constant electrical power series are the cheapest alternative but can overheat if overlapped. Also if the cable has a break somewhere, the whole cable will not work.
- Constant electric power zone is working on the same principle as the former model except a heating element is wrapped around two parallel bus wires and on alternating sides a notch is made in the insulation. The heating element is soldered on the exposed conductor. This is an improvement from the former model since one of these heating zones can fail without affecting the rest of the cable. Still prone to overheat if overlapped. (Seth, 2001)
- Self-regulating heat tracing cable's resistance varies with temperature. If temperature is low the resistance is low, and vice versa if temperature is high, resistance is high. When the temperature reaches the desired set point the resistance will go high and the heating will stop. This means also that heat will be applied to the portions along the cable where it is needed. This type of cable cannot overheat but are instead subject to high inrush currents, which mean the contactor used has to be able to handle this. (59)

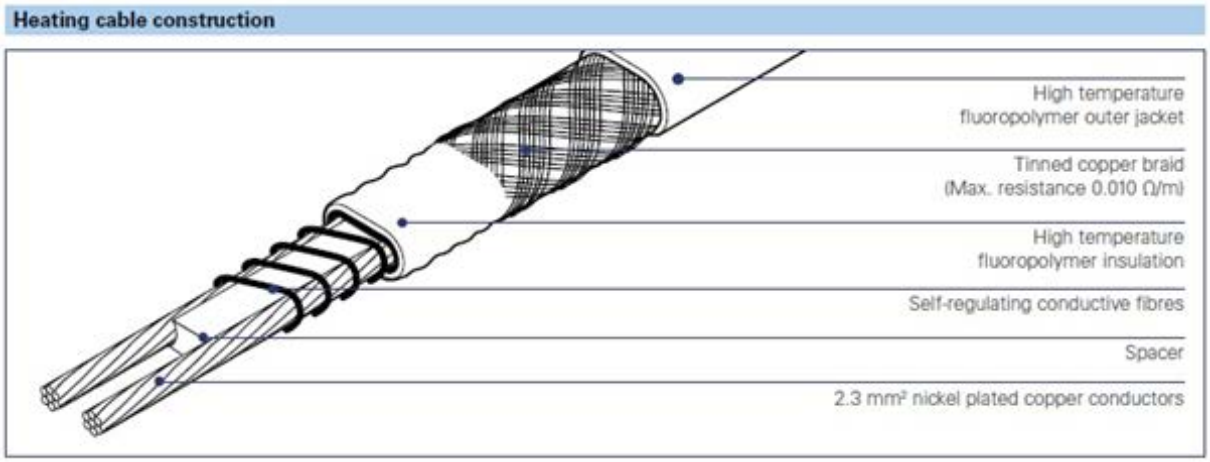


Illustration 46.- Heating cable construction

In the illustration above there is a better description how the self-regulating heating cable can look like (illustration 46). There are several companies that manufacture these kind of heating cables and tapes. The two most interesting ones are Pentair, HTSAmptek and BriskHeat.

An example on a heating cable is Raychem XTV 4XTV2-CT-T3 self-regulating heating cable, made by the company Pentair. The cables dimensions is 7,2x11,7 mm with a weight 170 g/m and the nominal power is 12 W/m and the voltage is 230V. (Raychem , 2012)

With a battery of 12 V:

I = P/U = 240 W / 12 V*1,1 = 18,18 A

t = C/I = 100 Ah / 18,18 A = 5,5 h on constant use

HTSAmptek offers both standard products as custom made solutions. These custom made solutions could be a very good idea for the project. The only problem here is that this solution is very expensive and especially since the order size of the Fibiod's product will be fairly limited. The standard products will allow to push back the total cost but they are in this case too heavy. The silicone tape can produce up to 760°C, which is far higher than the 30°C necessary to preserve to right viscosity of the biodiesel.

Power Density	**Up to 13.0 w/in² (2.0 w/cm²)**
ASR Silicone:	450°F (232°C), max exposure 482°F (250°C)
Voltage:	6V to 480V – DC, AC, 1 or 3 phase
Heating Element:	Mono, Duo, & Trio knitted alloy
Area Classification:	Non-Hazardous
Temperature Sensors:	Thermocouple or RTD (Process &/or Limit)
Lead Wires:	Nickel or CuNi alloy, sleeved,armor
Area Classification:	Non Hazardous

Table 15.- Custom made solution

Illustration 47.- Examples of custom made heating elements by HTSAmtek http://heatingtapes.com/collections/industrial-custom-tapes

Power density:	**3.25, 8.67, & 13.0 w/in² (0.5, 1.4, 2.0 w/cm²)**
Watts, Volts:	39W to 1248W, 120V or 240V
Lengths:	2ft (60cm) to 16ft (480cm)
Widths:	½ in (1.3cm) or 1in (2.5cm)
Heat Capability:	1400°F (760°C)
Lead Wires:	24in (60cm) on one end of the tape

Table 16.- Specifications of the silicon heater tape

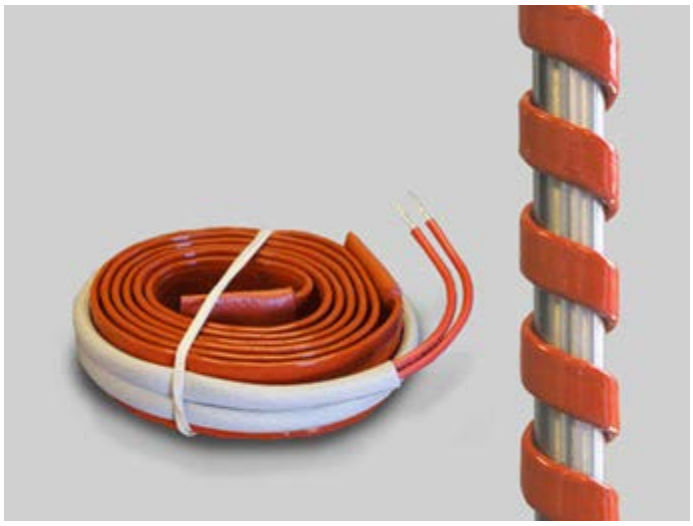


Illustration 48.- Silicone heating tape http://heatingtapes.com/collections/silicone-industrial-tape

The products that Briskheat offers are very similar to these of HTSAmptek. The advantage of BRiskheat is that their solutions are less powerful, which in this case is a good thing. The possibilities of customizing a solution are fairly limited but there are several good options available.

CLOTH HEATING JACKET

The so called heating jacket functions as a sleeve that can be wrapped around the fuel lines. It can heat up to 250°C and is resistant against the corrosive properties of the biodiesel. The best characteristic of this product is probably that is already very well insulated and thereby very energy-efficient. This piece of technology might however be a little too complex for a simple heating problem.

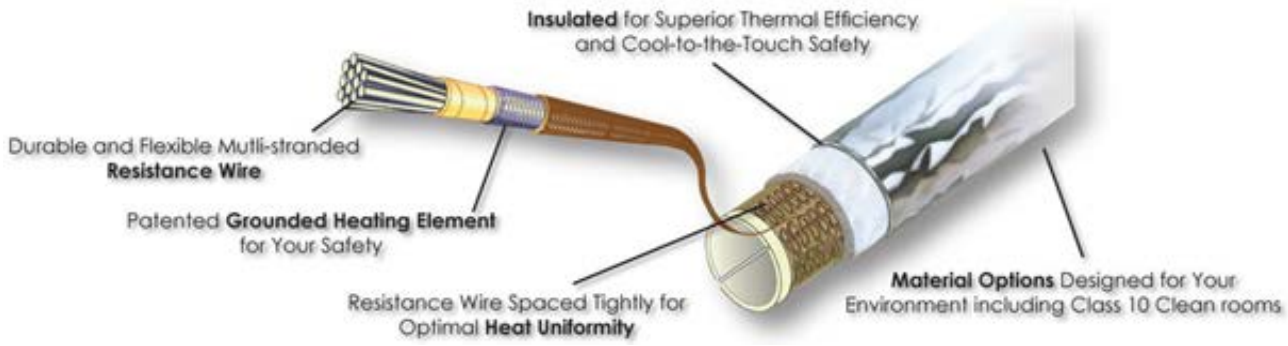


Illustration 49.- Cloth heating jacket by BriskHeat http://www.briskheat.com/p-553-cloth-heating-jackets.aspx

SILICONE TRACING TAPE

This product is very similar to the one from Amptek. An important difference however is the application wherefore this tape was designed are rather 'light duty'. This means a cheaper product. The advantages stay the same however, the tape will transfer the heat nicely to the pipe due to the flat shape of the tape and the cohesive silicon surface.

Specifications

- Maximum exposure temperature: 450°F (232°C)
- Silicone rubber extruded outer sheath
- Fiberglass knitted and braided construction
- Moisture and chemical resistant
- Power density: 4.3 watts/in2 (0.007 watts/mm2)
- 120 or 240VAC

Illustration 50.- Silicon tracing tape by Briskheathttp://www.briskheat.com/popup.aspx?src=images/product/large/320_1_.jpg

HEATING FOR THE FUEL TANK

SILICONE RUBBER HEATING STRAPS

These heating straps are sold by a lot of companies. However the specifications of the straps do differ between these companies. The ones mentioned below give a good average of the specifications of these heating straps. Since the heating is done on the outside of the barrel, extra insulation will be necessary to maintain the energy efficiency. The prices of these belts range from 150 euro to 200 euro for one belt. An advantage of this system is that the amount of belts can be adjusted to the size of the tank. This results in a standardized solution which will be a big benefit for the final concept.

Specifications

Thermostat Range (°F)	**50–160**

Amps	**3**
Volts	120
Watts	300

Illustration 51.- Heating straps http://www.tempco.com/tubular%20process/Drum%20Heaters/SiliDrum.htm

INSULATED DRUM HEATERS

These type of heater comes with the big advantage that they are already very well insulated. Just as like the heating belts, these drum heaters are available in several different sizes and with different specifications. The specifications mentioned bellow are most common and adequate for the problem.

These heaters are ready for use immediately since they just need to be connected to a power source.

Amps	3.33/6.67
Volts	120
Watts	400/800

Table 17.- Specifications for the insulated drum heaters

Illustration 52.- Drum heater with insulation http://www.northerntool.com/images/product/2000x2000/164/16495_2000x2000.jpg

HEATING FOR THE FUEL FILTER

The last part that should be heated at all times while using the biodiesel is the fuel filter. When the viscosity of the biodiesel is bad the filter will get clogged more easily. Resulting in more maintenance hours and higher cost due to the replacing of the filter cartridges. There are two good options that can offer a good, affordable solution for this problem.

GREENMAX FUEL FILTER/WATER SEPARATOR

This filter serves both as a heated fuel filter and as a water separator. The warm return fuel from the engine will be used to heat the fuel passing through the filter and going to the engine. This is a very efficient way of heating since it uses a heat source that will not be used for anything else. If necessary, the filter can be equipped with a 300W electrical element. This can be necessary to ensure that even when the engine stops or fails for some reason, the filter will stay warm and therefore the biodiesel will not clog.

Illustration 53.- GreenMax fuel filter http://solutions.parker.com/GreenMAX

The GreenMax Fuel filter is equipped with a water separator. This might seem like a good thing. However when using biodiesel this type of water separators will not work properly. The system works with a chamber at the bottom of the filter where, since water is heavier than diesel, will collect. With biodiesel, the water will partially be absorbed in the fuel and these kinds of separators will not work as well.

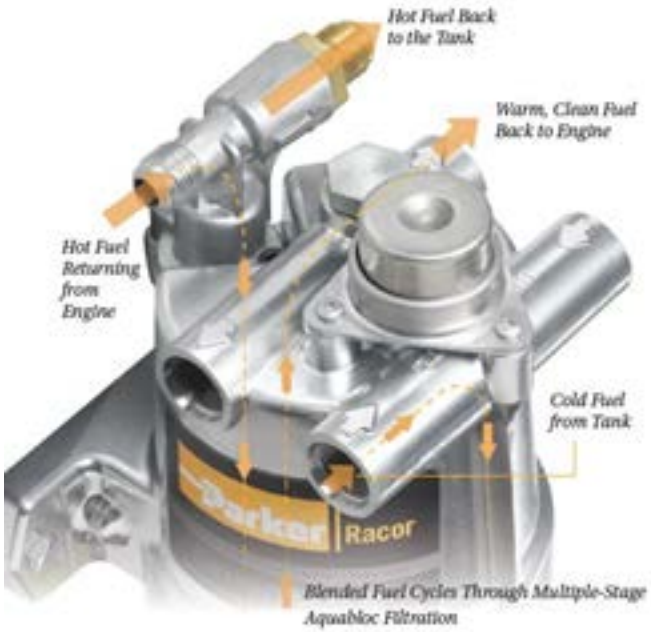


Illustration 54.- GreenMax fuel filter heating system http://solutions.parker.com/greenmax-heater

Raw power fuel filter heater

Another solution comes from the American company Utah biodiesel supply. The product they developed is a heating blanket that can be wrapped around the filter. The blanket uses electricity and is available in two sizes that fit most of the standardized fuel filters. The small blanket uses up to 100W whereas the large blanket uses 200W. This solution is extremely easy to install since it just has to be wrapped around the filter and closed with Velcro.

Illustration 55.- Fuel filter heating blanket http://www.utahbiodieselsupply.com/fuelfilterheater.php

4.3.3.2. HEATING WITH COOLING FLUID

How a marine cooling system works.

The cooling system is designed to remove excess heat from the engine and its components for optimum operating efficiency. There are two different methods for cooling down the system (55):

- **Open** cooling system: In this first method is used the raw water (seawater) directly in the entire system for cooling.

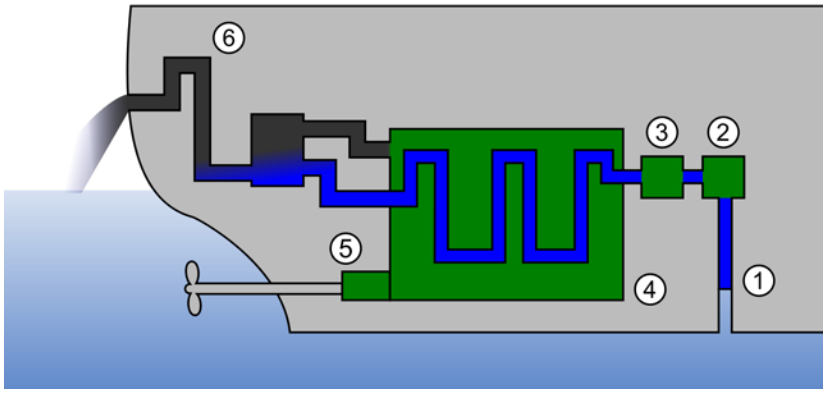


Illustration 56.- 1. Cooling pipes cooled itself by seawater. 2. Pump 3.Filter 4. Diesel engine 5. Clutch 6. Outlet pipe for exhaust fumes (56)

- **Close** cooling system: a close cooling system utilize a more complex, two stage system for cooling the engine. It incorporates a multiple chamber component called the heat exchanger, which allows the sea water to cool down the cooling liquid (antifreeze or fresh water generally) while keeping the two components separated. The water that is taken from the sea is only used to cool the heat exchanger, after that, the raw water is expelled with the exhaust gases from the engine.

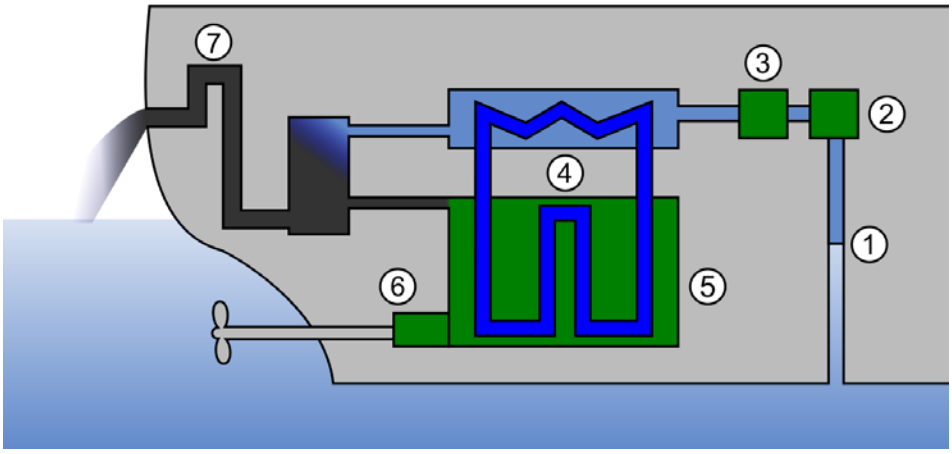


Illustration 57.- 1. Valve 2. Pump 3. Filter 4. Cooling pipe filled with chemical cooling substance or fresh water cooled itself by seawater in the heat exchanger 5. Diesel engine 6. Clutch 7. Outlet pipe.

During cold temperatures, the biodiesel will reach a high viscosity, awful for the optimum function of the engine, pipes, pump and filters. The solution to that is working with a pre-heating solution for the biodiesel. A good way to heat the biodiesel without using extra energy is to take advantage of the high temperature of the cooling system. The water or chemical cooling liquid goes out of the engine at about 60-80 °C, that temperature can be used to warm up the biodiesel in the storage tank.

Inside the fuelling system there are multiple components that need to be heated to make the system function properly. These components are fuel lines, the fuel filter and the main component is the storage tank. To heat these components with the use of the engine heat there has to be some kind of exchanger.

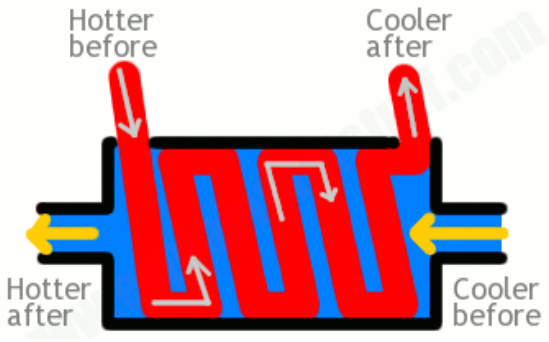


Illustration 58.- Inline Heater (78)

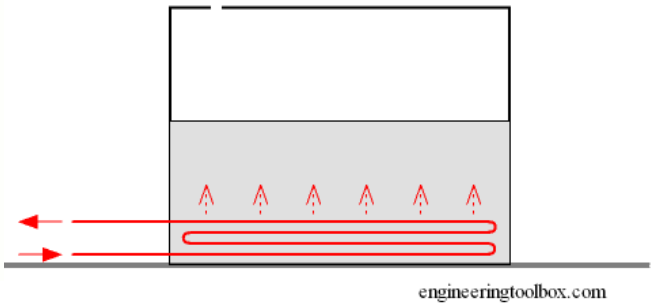


Illustration 59.- In tank Heater

The most common heat exchange method consists of copper tubing that contains a hot liquid and is placed in a substance that needs to be heated. This method is also reversible when you need to cool something down. There are two different methods, inline heater (heat exchanger) or a in tank heater.

The advantage of a inline heater is that there are two currents passing each other constantly, this makes the heater more efficient. The downside however is that you need two liquid substances to use this system, and because we have to deal with frozen biodiesel the in tank heater would be the better choice.

Illustration 60.- Flexible Heater

These heaters use primarily copper tubing to transfer the heat, but there are more options than normal copper tubing. The plain copper tubing that is often used in these applications is pre-bend by a machine or a mechanic with special tools, but there is a semi flexible copper tubing on the market that can be bend by hand to pretty much any desirable form. (57)

There is also a copper tubing on the market that is fitted with small fins to increase surface area and make a quicker heat

Illustration 61.- Heater Pipe with Fins (79)

transfer. At this point it is important to remark that every copper material in contact with biodiesel should be replaced with stainless steel or aluminium.

The fuel lines that run from the tank to the engine are also a target area that needs to be heated, this can also be done by the use of the cooling water from the engine. To transfer the heat multiple small copper tubes are bend around a pipe. This application can only be used with a hard pipe system, so no flexible application.

Illustration 62.- Pipe Heater (77)

To save energy and money, the existing diesel tank in the boat (100-300 litres) should be used as the biodiesel storage, it must be clean and dry before placing the biodiesel inside. If the diesel tank will be used as the biodiesel storage it is important also to check which is the material that will be in contact with the biodiesel, therefore, steel, plastic, brass, zinc, lead or copper must be change by aluminium, stainless steel or synthetic materials such as nylon, teflon, viton or nitrile rubber.

4.3.4. AUTOMATION OF THE SYSTEM

The final solution has to be automated as much as possible in order to make it reliable and easy to use. The fisherman does not want to have to remember a lot of information because the human factor will be the first cause of failure. According to the solution the system will have to execute some basic actions such as switch electro valves, read sensors, start additional systems like heaters, pumps …

Currently there are different hardware's that can pilot a system like this one on the market:

- The Arduino card (or similar), as it is explained in the pressurized bag solution (see page 57)
- A Programmable Logic Controller (PLC)
- A Raspberry Card (or similar)

The Programmable Logic Controller:

This component works in the same way that the Arduino card but it is more adapted to industrial situations. It is especially adapted to do repetitive tasks like in an assembly line for example, but in our case it could be a sustainable solution to the Arduino.

Good points:

- Extremely reliable
- Long life cycle
- Easy to install / replace

Bad points:

- Expensive (several hundred euros)
- Not adapted for boat environment
- Cannot read analogic values

Illustration 63.- SIEMENS PLC

It also has to be programmed, but this time, with a graphic code derivate from the Petri net (the base of sequential systems). This code so is sequential which means that the PLC will follow instructions that are given in a precise order, and it will not be able to go backward except if the program allows it.

The Raspberry Card:

Similar to an Arduino card in appearance, but very different, this card is a real computer itself. It is necessary to first install an operating system like Windows, the most common one uses Linux, then it needs an SD card as memory and it is ready to use. The card is equipped with USB, HDMI, JACK, ETHERNET ports so it can really be connected to devices like a computer. Usually this kind of card is used in embedded systems but it can also work as
a media server.

Good points:

- Reliable & good life cycle
- Complete and really adaptable
- Easy to install / replace

Bad points:

- More expensive than Arduino
- Too extensive

Illustration 64.- Raspberry PI card : www.raspberrypi.org

5. FINAL SOLUTION

5.1.INTRODUCTION

For most boats the flow chart will look like the flow chart on illustration 65. A pump takes the fuel to the engine, meanwhile it passes a filter. A return line takes the remaining fuel back to the tank. The engine will be cooled with either a closed water system or a system that uses the sea water. The entire engine system, including the pump is powered by a battery.

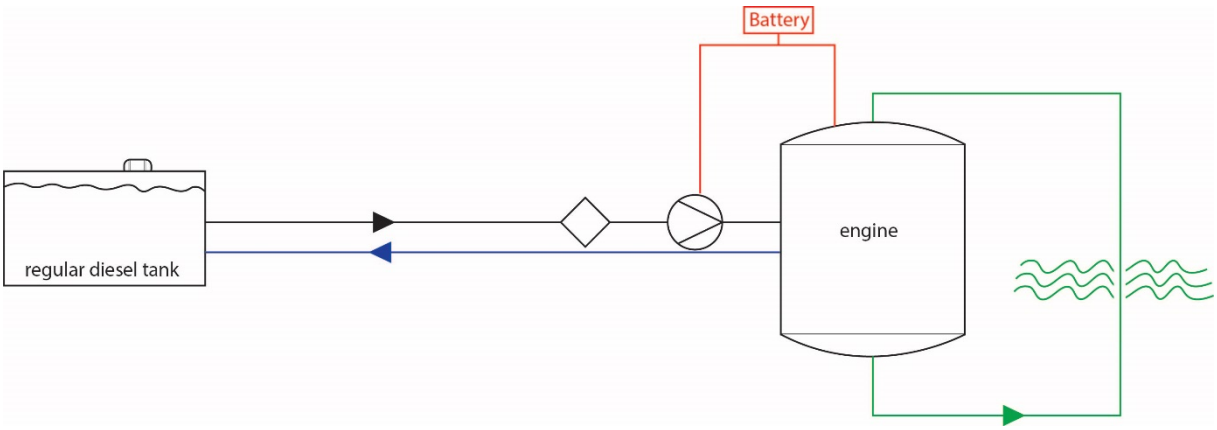


Illustration 65.- Flow chart of original - A. Bienstman

The second flow chart shows the improvements that need to be made in order to use the biodiesel. A new tank will have to be added, whether this new tank will be used for the biodiesel or the regular diesel will depend on the size and material of the old tank. The fuel lines of both tanks will be connected to the main line and will be separated by a two-way valve. The same goes for the return lines. Both the main fuel line and the return line will be isolated together in a heated coil. The return line contains fuel heated by the engine and will thereby help to warm the main fuel line. The filter will be packed in a heating blanket. The blanket and the heating coil will be powered by a newly placed battery. Heating the biodiesel tank will require a lot of energy. In order to be more energy efficient the cooling water of the engine will be used here. Depending on the type of cooling the heat will be transferred by a heat exchanger or by expanding the cooling circuit. To prevent water contamination the biodiesel tank will be equipped with an air filter.

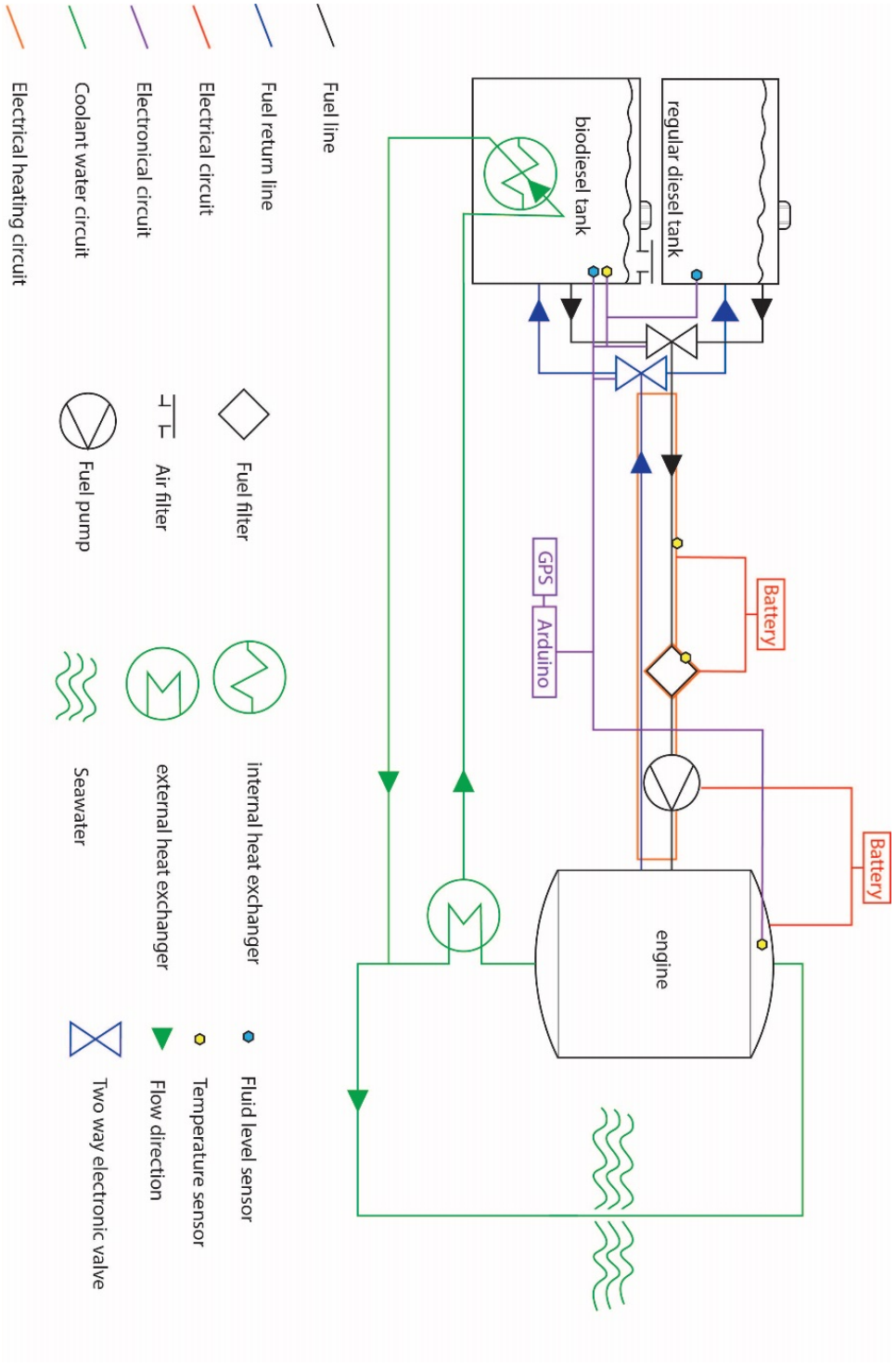


Illustration 66.- Flow chart Fibiod system - A. Bienstman

5.2. WATER CONTAMINATION

After analyzing the advantages and disadvantages of each solution the super absorbent polymers based tank dryer seems to be the best solution. This result is based on the ease of handling this tool and its cheap price.

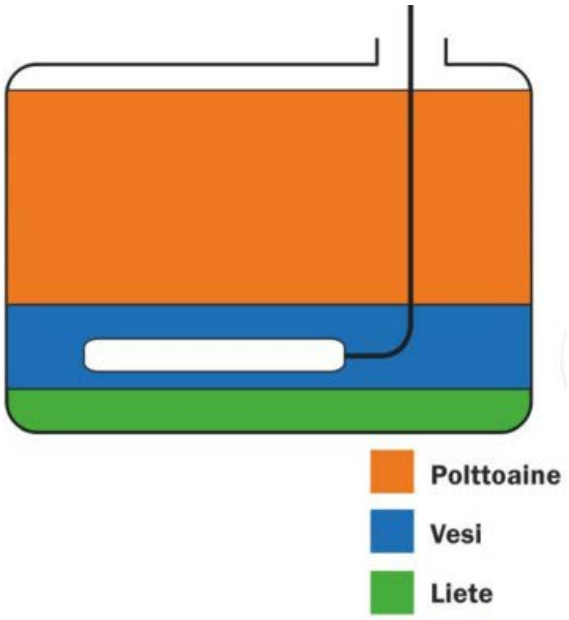
Illustration 67.- Real usage of the tank dryer (58)

Illustration 68.- Commercial tank dryer (58)

When using a absorbent polymers based tank dryer it is good to know some facts (58):

- The tank dryer will absorb water, and will expand. It should be checked weekly and removed when swollen. It can absorb 350 ml of water, this means when a good quality biodiesel is used, the tank dryer should be change 3-6 times per year.
- It should be placed in the bottom of the tank, this is where the water will be located (illustration 69).
- When installing this tool it is important not to obstruct the fuel outlet or sending unit.
- If you are using already any kind of additive in the bio diesel for diminishing the water content, the effectiveness of the tank dryer will be reduced.
- It will not work with ethanol blends.

The result of using this tool is an instant decrease of water in the bio diesel and as a result a high diminish in the engine downtime and the maintenance costs will be cheaper. It is also a product easy to find and buy in Finland, the prices are showed in the next Illustration (69).



TUOTENRO	NIMIKE	MITAT	KPL/PKT	HINTA
CTS1901	CIM-Tek Tankin vedenpoistoliina	59 cm, naru 220 cm	1	24 €
CTS1902	CIM-Tek Tankin vedenpoistoliina	59 cm, naru 220 cm	12	250 €

Illustration 69.- Price list for the tank dryer coming from a Finish supplier. www.ikalog.fi

5.3.HEATING THE BIODIESEL

The next step is to develop and study a module to heat the biodiesel tank by the excess heat coming from the cooling system of the engine. By this way, when the engine is working and warm enough it could transfer part of that heat to the fuel, providing the biodiesel a optimal viscosity to flow inside the pipes, go through the filter and get driven by the pump to the engine.

5.3.1. PRESENTING THE SYSTEM FOR HEATING

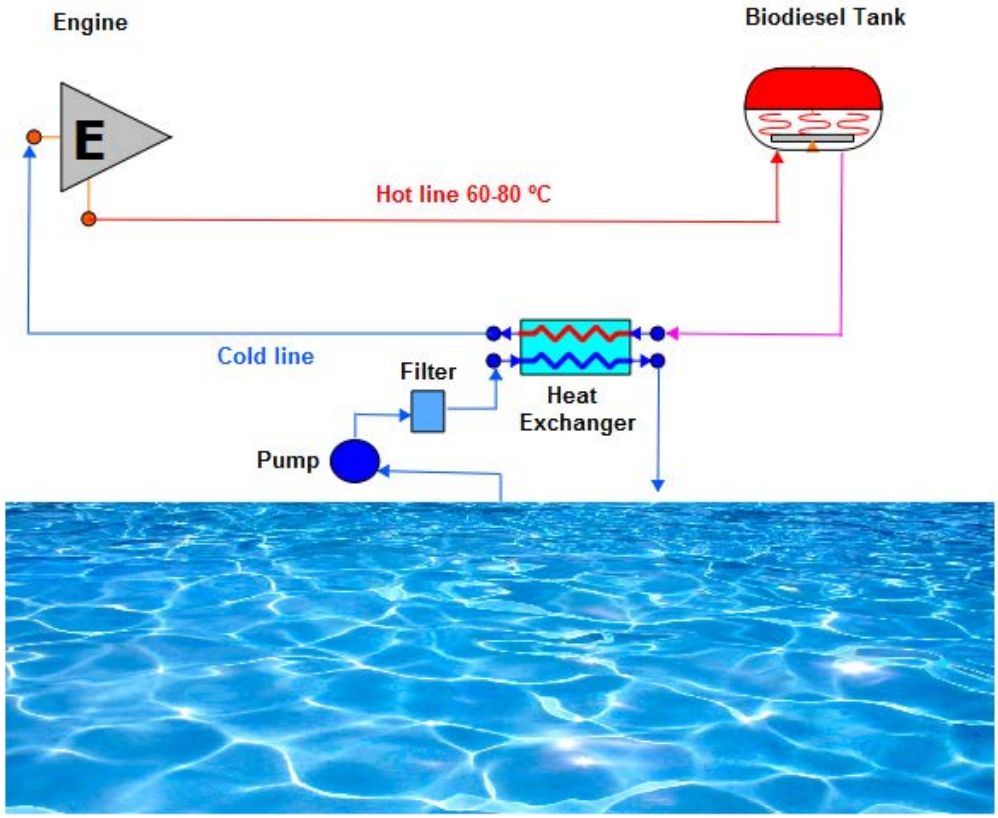


Illustration 70.- Scheme of the cooling system (warming the biodiesel tank)

As it can be seen in the illustration (70) the biodiesel tank is heated by the warm liquid that come from the engine. Once some of that heat is transferred to the biofuel, it goes directly to the heat exchanger, which takes raw water from the sea to exchange heat with the coolant fluid. The result of this process is having constantly cold liquid to cool down the engine.

Since the first moment that the engine is running the biodiesel will start to warm up, this means that in the beginning, most of the heat from the coolant fluid will be transmitted to the biodiesel, however when the biodiesel is melted and warm enough, most of the heat will be exchanged in the heat exchanger with the seawater.

Most of the fishing boats have already a heat exchanger based close cooling system with the respective valves, a pump (to take the raw water from the sea) and a filter (to clean the water before going inside the exchanger).

Before implementing this method into a fishing boat is important to know and be able to difference the three most commonly used cooling systems for a diesel engine and to know its pros and cons as well (59):

- Open or direct cooling of the engine by sea water. It is inadequate due to the fact that the engine (possibly initially designed for radiator cooling) is not prepared to work with that cold temperatures and the corrosive sea water can damage the cylinder block and heads.
- Keel cooling. It is the least common of all, but it can be found in small boats operating in shallow weedy water. It works with a pipe system out of the hull, which entails a big limitation.
- Heat exchanger based cooling system is the most common one. It is the one that it is presented in the illustration 57 . The raw water is not mixed with the coolant liquid, so the entire system is not exposed to the corrosive sea water. Normally the exchanger is a tubular heat exchanger or a shell and tube heat exchanger (illustration 71, 72) .

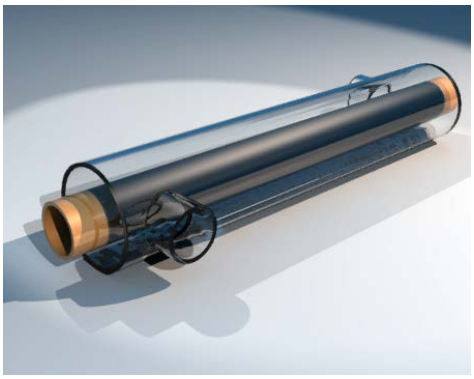


Illustration 71.- Tubular heat exchanger (60)

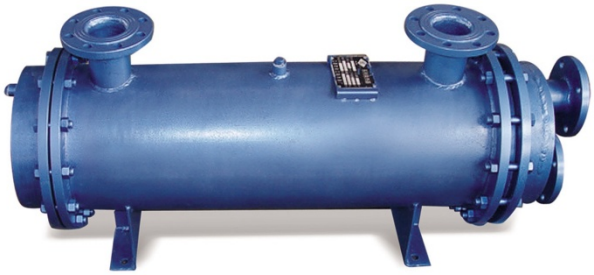


Illustration 72.- Shell and tube heat exchanger (60)

A water cooling **pump** is an important part of any marine cooling system as it supplies a continuous flow of raw water to maintain the temperature demanded from the engine. It is known as a flexible impeller pump that provides sea water to the heat exchanger to cool the engine. This pump can be based on a pulley, electric, gear or crankshaft mounted. (61)

Illustration 73.- Pulley Driven Engine Cooling Pump (61)

Illustration 74.- Electric Circulation Water Pump (61)

The **filter** in the cooling system (Illustration 75) is not as important as the pump because the sea water is operating in a close circuit, making contact only with the pipes and the heat exchanger. On the other hand it is a good investment for increasing the life of the heat exchanger and the pipes as well. It can take apart the impurities and debris from the seawater.

Illustration 75.- Seawater filter (62)

5.3.2. IMPLEMENTATION OF THE SOLUTION

To take advantage of the cooling system for heating the biodiesel tank, a pipe transformation should be needed. The actual cooling system of the fishing boat does not need to be modified, however the hot line coming from the engine must be redirected to the biodiesel tank (illustration 76 right).

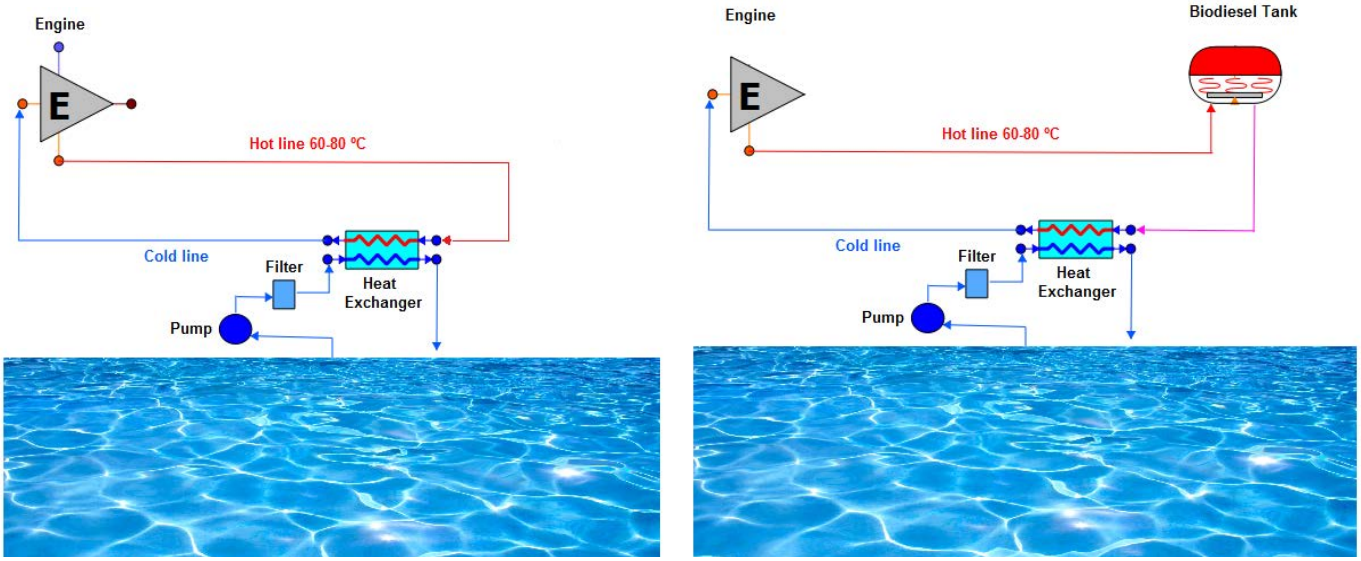


Illustration 76.- Comparison between original cooling system of a fishing boat (left) and the implemented solution for warming the biodiesel tank (right).

As it can be seen in the illustration 76 right, the hot line should be adapted to go inside the biodiesel tank with the final purpose of transfer the heat to the biofuel. That modification should be analyze following the next steps:

- The elongation of the pipes will be done with adapters, it will depend of the kind of material that the pipes are made of. Materials commonly used for the manufacture of cooling system pipes and tubes for marine use are steel and low alloy steel, copper, brass and several alloys of copper-nickel. Non-ferrous pipes are used especially for systems of the following types: condensate, fresh water and salt water, lubricant and fuel oil, compressed air and hydraulic cooling action. High pressure steam is carried in pipes made of molybdenum alloy carbon steel. (63)

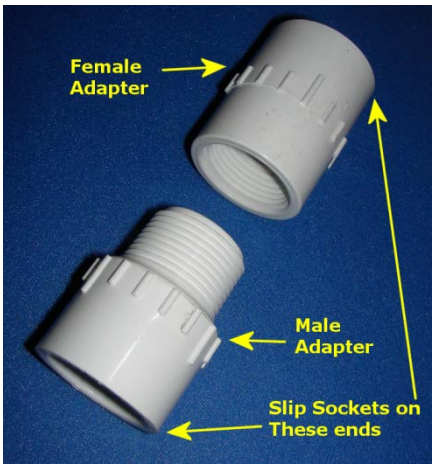
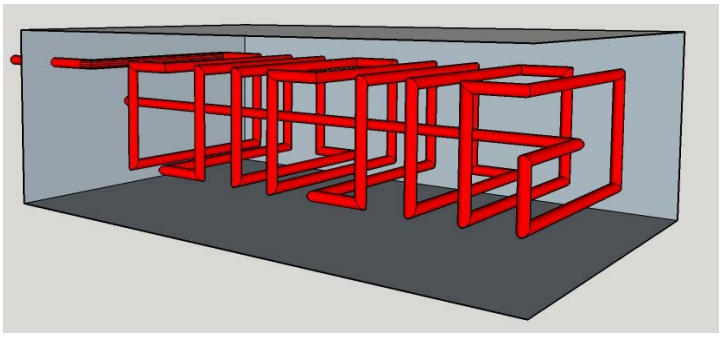


Illustration 77.- Adapter between pipes (64)

- The second part of the hot line should be made by aluminum, as it is a good material to transfer the heat between water flowing inside and the biodiesel around the pipes. It is also a excellent material to endure the corrosive action of the biofuel. Different 3D models have been created to study how the system will work.



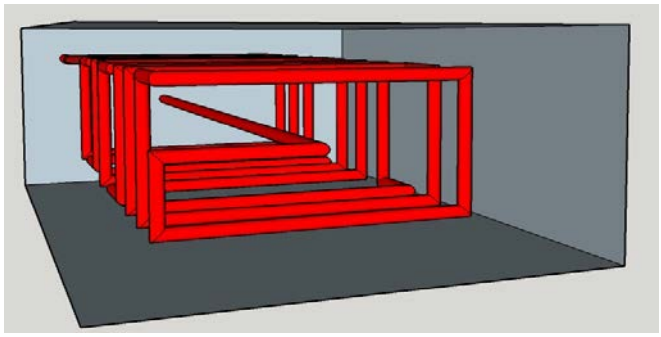


Illustration 78.- 3D model of the tank heater (design 1)

Finally, the design 2 has been chosen as the solution for heating the biodiesel tank (illustration 79). The heat exchanger is placed in the bottom of the tank, same place where the water comes in and goes out. On the fuel outlet it can be seen two different nozzles, one for the outgoing of the biodiesel and the other one made for the returning line from the engine. Sometimes the engine doesn't need that much fuel that the pump delivers, so it is coming back to the fuel tank by the returning line.

The heat exchanger is based on tube bundles made of aluminium (illustration 80). This material is an excellent alternative over the copper tubes. Aluminium heat exchanger compared to a copper based is lighter, it has better corrosion resistance due to a better galvanic balance and is more cost-effective (65).

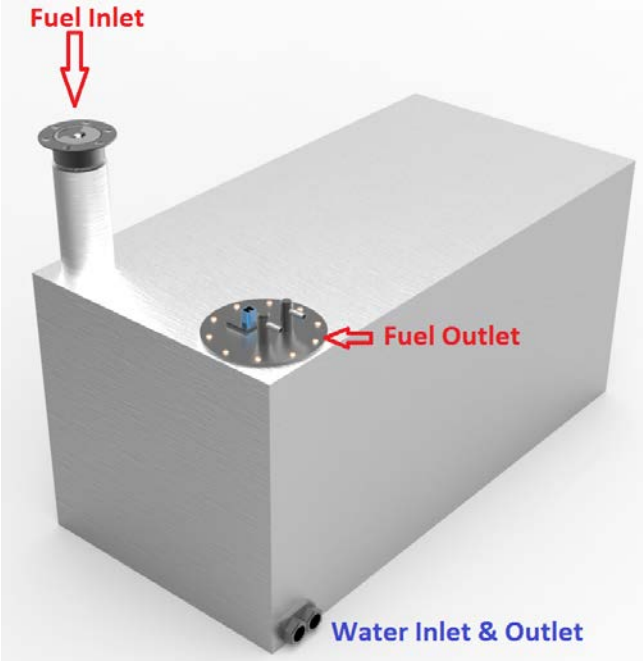


Illustration 79.- 3D model of the biodiesel tank (design 2)

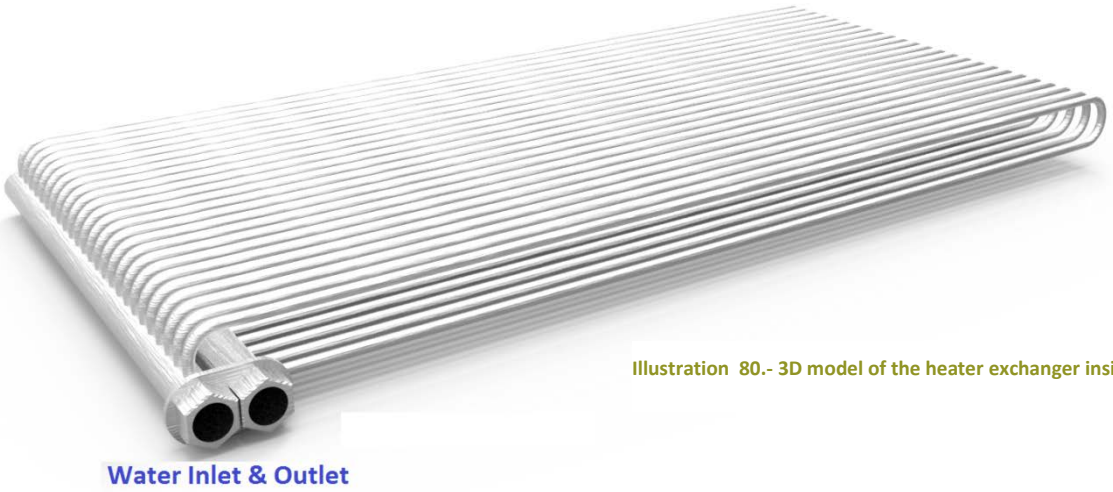


Illustration 80.- 3D model of the heater exchanger inside the biodiesel tank (design 2)

It is also important to say that the biodiesel tank will work with an air filter positioned on top (illustration 81), removing the moisture of its interior, diminishing the water in the fuel. This air breather is made with the main purpose of exchanging air between the inside and outside of the tank. As the biodiesel level changes inside the tank, air passes through the breather. When the wet and dirty air enters, a 2-micron filter removes the particulate matter. Then, the silica gel (an excellent absorbent material) removes 90% of water vapour from incoming air. Finally the air passes through an activated carbon filter and a second contaminant solid filter. The activated carbon removes the biodiesel residue from outgoing air. When the breather reaches all its water vapour capacity it turns green, then it must be replaced (66).

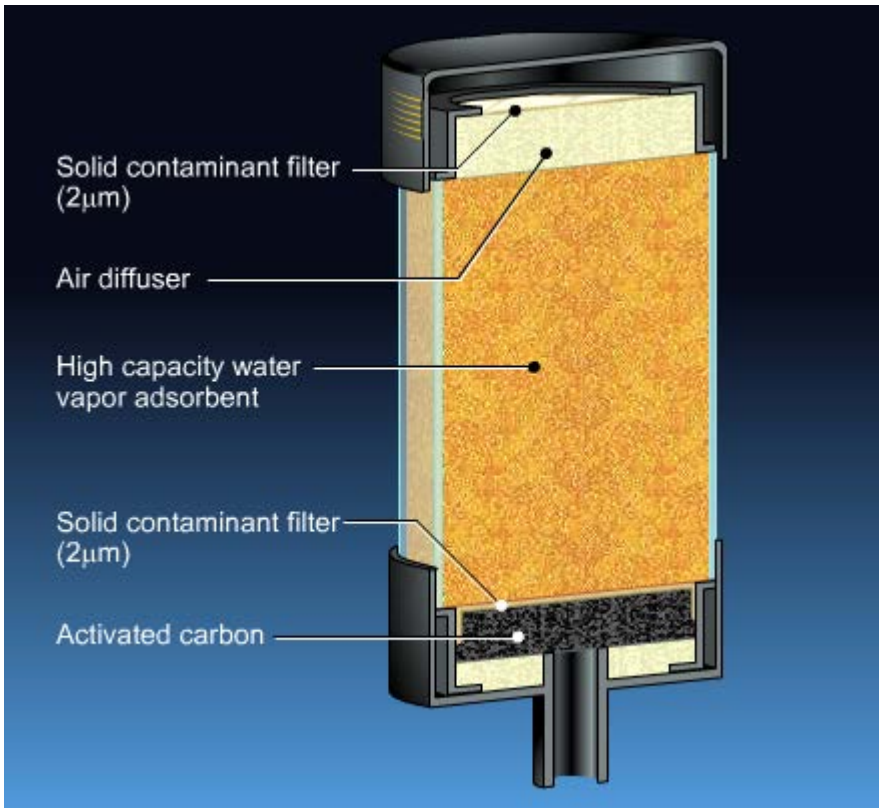


Illustration 81.- Cross section of a Air tank breather (66)

There is a supplier of these air breathers in Sweden (Ramby, Roselund), the price of one is 180 € coming from this supplier; http://www.rovab.com/. There are cheaper air filters in the market as well, however this one have been chosen because is the one that Feora Oy (biodiesel company in Finland) uses on their biofuel tanks.

Two different sensors will be needed inside the tank.

- **Fuel level sensor** (illustration 82) consisting on a floater attached to an electric wire connected to the controller (arduino). The float sensor will go up and down along with the biodiesel level.

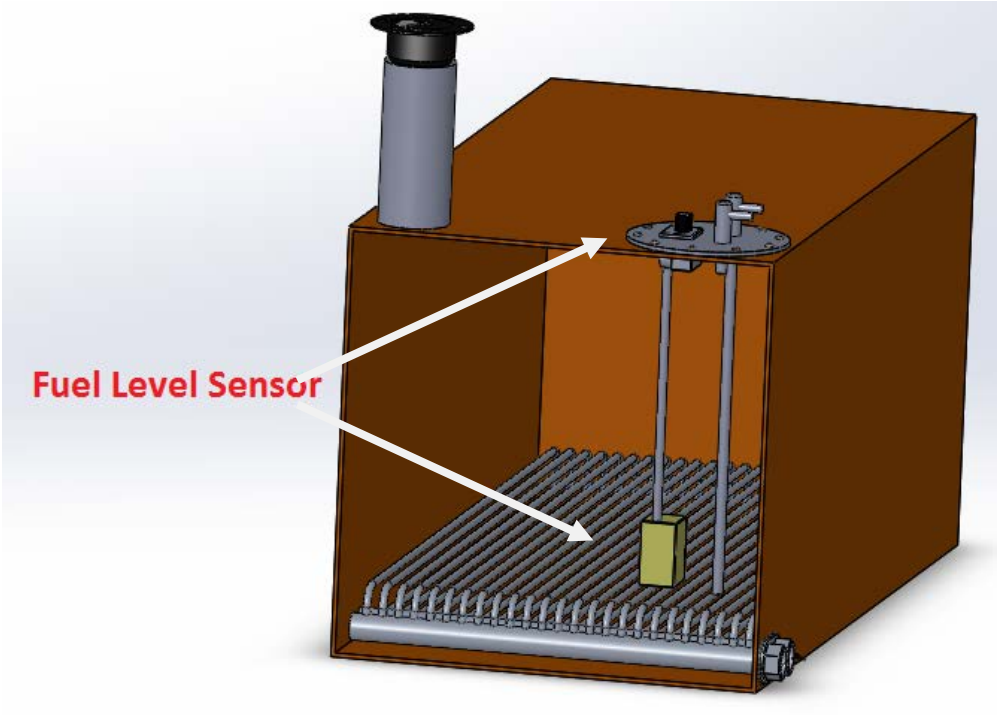


Illustration 82.- 3D model of the biodiesel tank

- A **temperature sensor** (illustration 83) attached to the "floater level sensor", able to read the temperature of the biodiesel, send the signal to the controller and then control the corresponding valves.
  This temperature sensor is waterproof and anti-rust. It is made by high-quality stainless steel tube and can be connected to any microcontroller. Because of his good quality, good properties and cheap price it will be the one used in the entire system. It can be used between -55 °C and +125 °C. The specifications are attached in the Appendix 2.

Illustration 8.- Waterproof temperature sensor DS18B20

5.4.HEATING THE FUEL LINES AND FILTER

The chosen solution is electrical. The main reason for this is that if something where to happen to the engine and the cooling water can no longer be used, the filter will remain heated.

5.4.1. HEATING THE FILTER

A common problem when using biodiesel is that when the biodiesel becomes colder, the gelling of the fuel can cause the filter to clog more easily. Heating the filter guarantees that the fuel will stay at the right viscosity to pass through without causing any problems. The final solution for this problem is a combination of an electrical heating blanket that can be wrapped around the filter and a hydronic heating cap. This type of heaters heats up really fast which is ideal since this reduces the start-up time for the boat.

Because this product is available in two sizes that will fit on all size of filters, the total cost for this solution will be relatively low compared to a custom made solution. The company that sells these products is UBS (Utahbiodieselsupply). Unfortunately there are no similar products available from Finnish companies.

Illustration 84.- Heating Blanket (left) and filter mount (right) (http://www.utahbiodieselsupply.com/fuelfilterheater.php)

- The heating blanket

The heating blanket works electrical and is available in two sizes. Though most boats will use the small blanket which is 75mm high and produces 100W of heat. It might be possible that some bigger boats need the larger, 150mm high and 200W heating blanket. Both heating blankets come with a 12 mm gauge wire that needs to be connected to the extra battery. The blankets can reach surface temperatures up to 150°c. This will be more than sufficient to keep the biodiesel from clogging the filter. The reason why this solution uses electricity instead of coolant is that in case something goes wrong with the engine, the diesel won't clog in the filter.

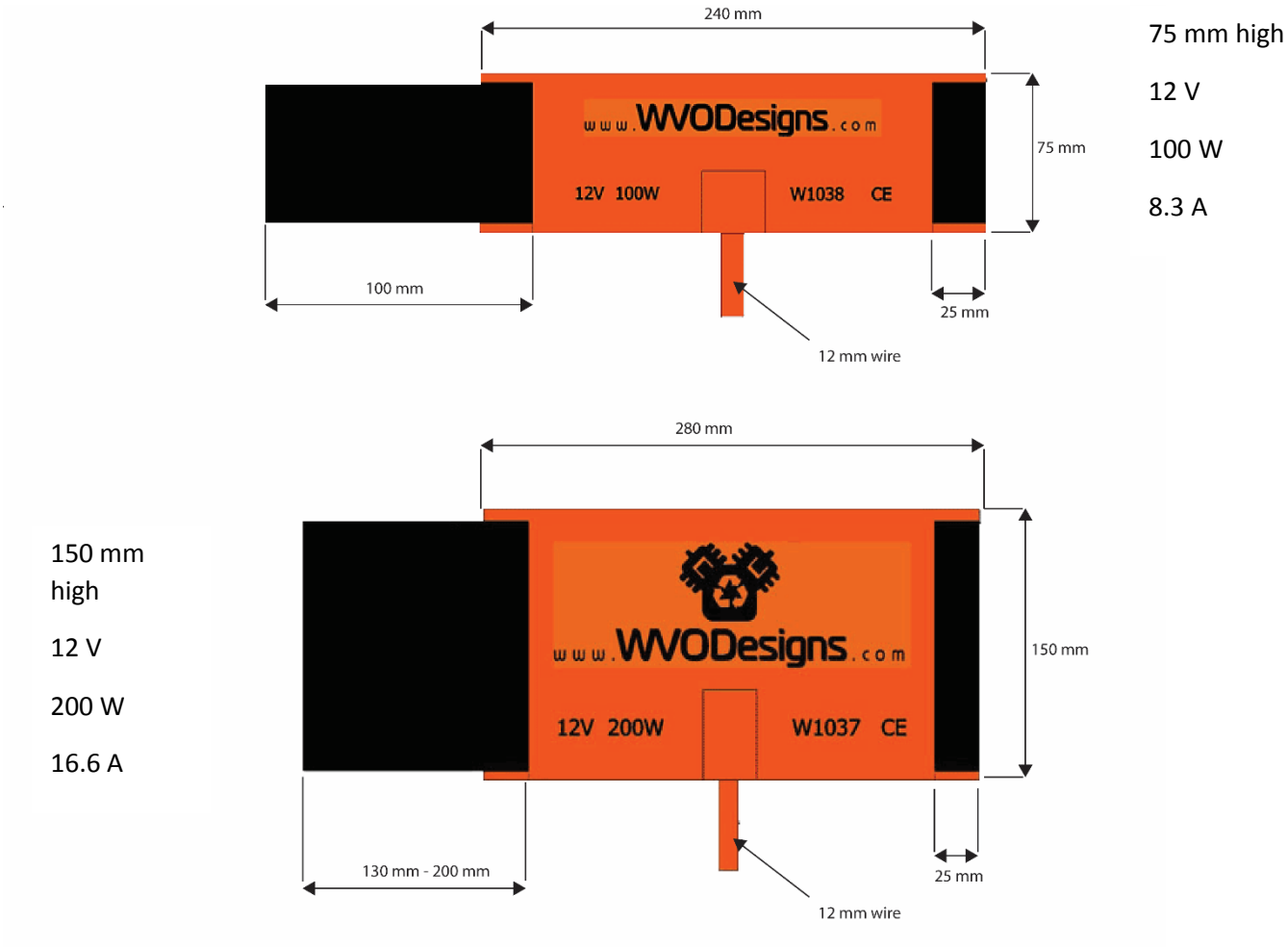


Illustration 85.- Measurements Heating blanket (http://www.utahbiodieselsupply.com/fuelfilterheater.php)

- Coolant heated Fuel filter mount

This filter mount doesn't use electricity but uses the coolant water from the engine. This means that less electricity will be used compared to using the heating blanket. Once the engine is heated, the fuel blanket can stop working. The coolant water flows through the part, the entrance and exit are indicated with a C, it's not important in which direction the coolant flows. The arrows on the mount indicate the input and output for the fuel lines. There's an input and an output at each side. This means that there are multiple possibilities of setting up the filter. In consequence, the filter mount can be used for a lot of filters which is a big advantage. The cap of the filter mount is available in different sizes, to fit each type and brand of filter.

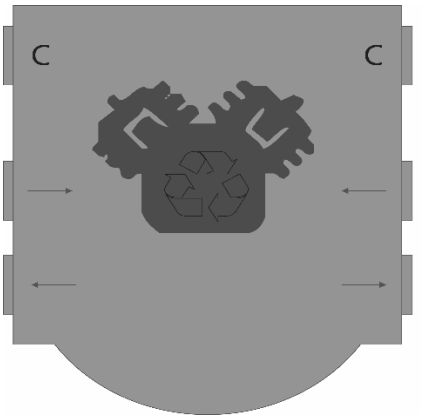


Illustration 86.- Filter mount by A. Bienstman

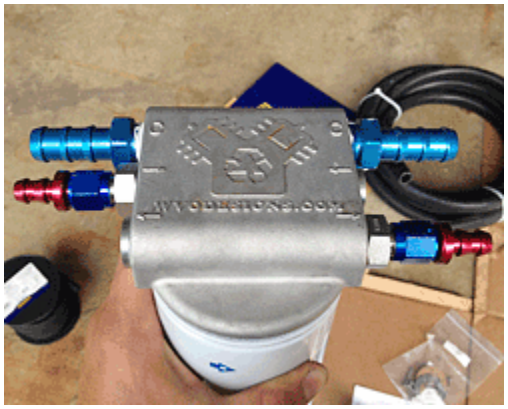


Illustration 87.- Filter mount

http://www.utahbiodieselsupply.com/fuelfilterheater.php

5.4.2. HEATING THE FUEL LINES

To keep the biodiesel warm in the fuel lines, a heating cable will be applied around the fuel lines. The heating cable are wrapped in a silicon tape. Because it has a flat shape this tape will trace and thereby transfer the heat nicely to the pipes. The tape itself is made out of a double braided heating element covered in silicones. These silicones guarantee a good heat transfer, good grip on the pipelines and protection for the heating element.

The silicone tape can be cut at length, this means that the pipes can be covered with exactly the right amount of tape. The result of this is a cheaper product since there will not be excess products.

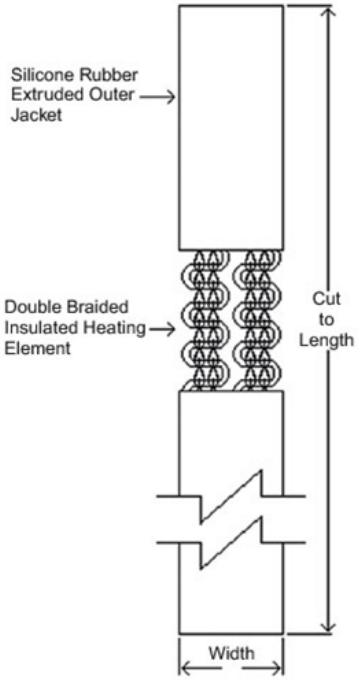


Illustration 88.- Schematic of heating tape http://www.briskheat.com/p-327-ctl-cut-to-length-silicone-rubber-heating-tapes.aspx

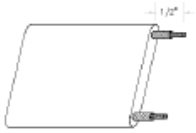
Illustration 19.- Tape around pipe and tape cut to length. http://www.briskheat.com/p-327-ctl-cut-to-length-silicone-rubber-heating-tapes.aspx

5.4.2.1. INSTALLATION INSTRUCTIONS

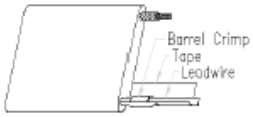
There are two terminations to the tape, a lead termination and an end termination. These next steps show how to finish these terminations after cutting the tape. These steps are necessary to ensure the safety of the tape and heating system. These steps will be executed by the Fibiod team when installing the system.

LEAD TERMINATION

The first step is to clean the silicone of the end of the tape so that 10mm to 15mm of wire is exposed.



The second step is to crimp the lead wires to the exposed ends using barrel crimps.

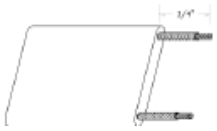


To ensure the safety, both barrel crimps should be covered with insulation tape.

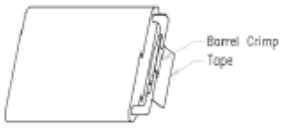
The last step is to cover the lead termination with silicone tape. It's important that the tape is wrapped tightly around the ending and no gaps or wrinkles are created.

END TERMINATION

The first step is to clean the silicon of the ends from the tape for 10 mm.



Next the two ends should be connected with a barrel crimp.



The barrel crimp needs to be covered in silicon rubber tape.

Once this done, the entire termination should be covered and packed in silicon rubber tape.

5.4.3. EXTRA BATTERY

In order to use all the extra heating tools an extra battery will have to be placed. The size of the battery will depend on the size of the boat. A larger boat will have more fuel lines to heat. Two sizes will be made available by Fibiod.

	Energy usage in Watts	
	Small boat (7m)	Big boat (12m)
Heating fuel lines	40 W	80 W
Heating filter	100 W	200 W
Emergency heating engine	490 W	490 W
Total	730 W	770 W

The total amount of Watts used will be 770 Watt/hour. This gives us the possibility to calculate the size of the battery the system will need. This is only when some type of engine failure occurs, normally the heating parts for the engine will be turned off. Further on the heating of the filter will be turned off as soon as the coolant water is warm enough to heat the filter through the filter mount. This means that after approximately 30 minutes the total energy use will be 40W or 80W.

As mentioned in the explorative part of this report, deep cycle batteries will give the most advantage and longest life-cycle in this application. Using a different battery for small and large boats isn't an option because the total energy needed in case of an emergency is almost the same.

To calculate the size of the battery we assume a worst case scenario. First there's half an hour using both filter (280W) and fuel heating after 8 hours of using the system in its normal state (80W) the engine fails and the emergency heating system runs for another hour (770W). The system requires a 12V battery. To calculate the total Watt used in one trip we use the amount of watts they use and for how long they use it.

Big boat 280W(0.5h) + 80W(8h) + 770W(1h) = 1550Watt/trip

Small boat 140W(0.5h) + 40W(8h) + 730W(1h) = 1120Watt/trip

The largest amount of Watt needed at a certain point is 770 Watt. With 12Volt this results in a usage of 60 Ampere.

The solution for this is a deep cycle battery of a brand named Trojan. This battery has an output of 12V and can produce up to 76 Amperes an hour.

BCI GROUP SIZE	TYPE	CAPACITY [A] Minutes @25 Amps	CRANKING Performance C.C.A. [D] @0°F	C.A. [E] @32°F	CAPACITY [B] Amp-Hours (AH) 5-Hr Rate	10-Hr Rate	20-Hr Rate	100-Hr Rate	ENERGY (kWh) 100-Hr Rate	TERMINAL Type [G]	DIMENSIONS [C] Inches (mm) Length	Width	Height [F]	WEIGHT lbs. (kg)
12 VOLT DEEP CYCLE AGM BATTERY														
24	24-AGM	137	500	600	67	70	76	84	1.01	6	10.77 (274)	6.84 (174)	8.62 (219)	54 (24)

5.4.4. CONTROLLING THE HEATING OF FUEL LINES AND FILTERS.

To make sure the system is used correctly and as energy efficient as possible it's necessary to control the temperature of both the fuel lines and the filter. A sensor will be placed on the filter to measure the temperature. Another sensor will be placed on the fuel lines approximately a meter before entering the filter. These combination of sensors will allow the controller to turn the electrical system on or off. The coolant heating mount will of course always be working since it uses the cooling water which should be always available.

5.4.5. INSULATION OF HEATED PARTS

When the biodiesel is heated it is important that this heat will not be lost due to the fact of radiation and heat transfer to the environment. Therefore it is important to isolate the places that are the most vulnerable to these circumstances, especially in the lines. In the lines the biodiesel is more vulnerable to heat loss because of the relative small amount of biodiesel passing through compared to the big surface area of the pipe, therefore a lot of heat is extracted by the surface area of the pipe. Not only the fuel lines should be insulated but also the tank itself to contain the heat as much as possible. There are all kinds of insulation materials, to find the right one there has to be kept in mind that the operating temperature in this specific application is going to be ranging from -40 to +100°C. This resulted in the following insulation materials.

Illustration 20.- Polyethylene Foam

- Polyethylene foam is a lightweight, durable, flexible and element resistant insulator. These properties make it a cost effective insulation solution. Polyethylene foam is on the other hand not fire proof, and only usable with temperatures ranging from 0 to 90°C. When Polyethylene gets warm it tends to shrink, this results in gaps in between the different pieces of insulation. Price is around €1,50 per/meter of insulation tubing.* (67) (68)

  Nitrile Rubber Foam insulation is a mainly closed cell insulation foam that can handle temperature ranging from -200 to 115°C. It is also non corrosive to other materials and has a good oil and grease resistance.

Illustration 3.- Nitrile Rubber Foam

  Compared to the Polyethylene insulation Nitrile rubber already has a fire safe property and is used often in marine applications. Price is around €3,50 per/meter of insulation tubing.* (69) (68)

- Fibreglass or Glass wool insulation is a wool that is made just like cotton candy but then out of recycled glass and sand particles. This recycling process makes is at green and cheap insulator that is fire and grease resistant, and

Illustration 4.- Fibreglass Wool

that does not corrode other materials. Compared to the other Insulators Fibreglass tends to lose its insulation value when temperatures drop. For example at 30°C it has lost 20% of its efficiency, Fibreglass also performs poorly in application places where there is a draft. Temperature ranges from -20 to 450°C. Price is around €5,00 per/meter of insulation tubing.* (70) (68)

All of the materials mentioned above are also available in sheet form, this way one material can be chosen for the different parts that need insulation for instance the flat surfaces of the fuel tank.

*The price information is from an American Do It Yourself web shop (71), these prices are only for the comparison of the different insulation materials. Prices from actual suppliers are hard to find, and will most likely differ when insulation is bought in wholesale.

THE APPLICATION

As the insulation application will also be in the engine compartment it is a must that the insulation has some kind of fire resistance property. Furthermore the temperature range of the insulation must be at least the same of greater than the temperature of the application. This leads to the most suitable insulation: Nitrile Rubber Foam, it is not the cheapest solution but that is compensated for by the pros of this material. The fact that Nitrile Rubber Foam is already often used in marine applications makes it a even more suitable choice.

Illustration 5.- Insulation layout around heated lines

5.5. 3D MODEL

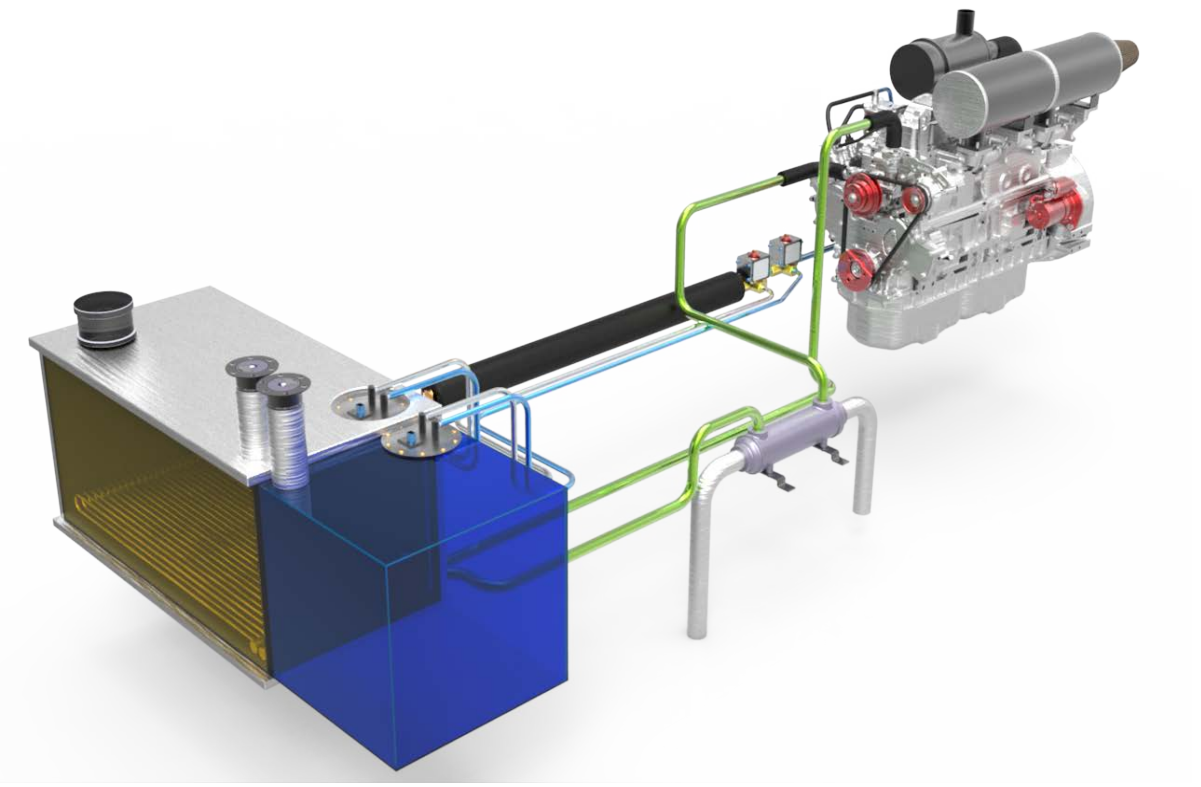


Illustration 94.- 3D model of the system

To make the concept solution more understandable a 3D model has been made by using CAD software, for this particularly model the software SOLIDWORKS was used. To keep time spending on the model limited an already existing model of an engine was used, a 6 cylinder Diesel engine. The model shows how all the different lines are laid out and how they connect to all the different components in the system. This also makes it easy to show how the insulation and heating solutions will be applied.

5.6.SECURITY

In this chapter the solutions for the engine heating are introduced. This will be a security system in case something were to happen to the engine in the middle of the sea or anywhere else. This solution's main task is to keep the engine warm and prevent the B100 from changing its viscosity in the cold weather, while the fisherman tries to fix the upcoming problem. This will also prevent the engine wear and increases the changes that the engine will start easier again.

5.6.1. ENGINE HEATING

The heating of the engine is important especially in the colder climates. This increases the changes that the engine will start easier and reduce the fuel usage, carbon dioxide emissions and engine wear. The heating can be done with an electrical heating element or on the vehicles own fuel supply. The electrical heating elements means precisely what the name says, converting electricity into heat though the element. Examples on these kind of heating's are, in-line heating system, heating pads, PTC rubber and heat tapes. These solutions were presented in chapter 4.3.3.1 named Electrical heaters.

Block heaters that uses the vehicles own fuel supply to heat up the engine, this is done by heating up the coolant and the heated coolant is pumped thought the engine and cars/boats heater core. These kind of heaters is used in newer cars made by e.g. Webasto Group, Eberspächer and Ardic.

In this chapter only the solutions where electricity heating is used are explained that are economical and easy to apply for heating up the engine. Even though webasto is mentioned, this is not explained more because of the Webasto being an uneconomical choice for the fishermen and it's not feasible to spend a lot of money to implement it when the winter season is not long enough.

The solution that was chosen for this case is a combination of two electrical heating systems that are the heating pad and the heating tape.

SELF-REGULATING HEATING TAPE

The self-regulating heating tape can regulate the temperature without using a temperature sensors and it can be applied on metallic or non-metallic pipes. It's also easy to install and can be cut on the working site. Thanks to the self-regulating property this cable can't overheat but are instead victims to the high inrush currents, which means that the contactor used has to be able to handle this.

These heating tapes would be used to heat up the fuel lines in the motor, incase if the engine shuts down for some reason in the middle of the sea while using B100. The idea is to prevent the B100 from changing its viscosity while repairing the problem or restarting the engine and changing the fuel to diesel. This heating method can also be used for heating up the engine before starting the boat in winter time, which also increases the changes that the engine will start more smoothly in colder weathers.

Illustration 95.- Pentair Raychem XTV

In this case scenario the Fibiod team would use Raychem XTV 4XTV2-CT-T3, see illustration 94, heating cable with a nominal power of 12 W/m and the voltage is 230. The dimensions are 7,2 x 11,3 mm with a weight 170 g/m, so the total weight is 3,4 kg. The needed cable length would be 20 meter, just to be sure that it's enough, and the price would be 70,0 €. For having 20 m of cable results to that the total wattage would be 240. With the help of the technical specs, it can be calculated that the heating cable could be in constant use for 5 hours and 30 minutes with a 12 V battery and a 240 V inverter.

This cable would be installed around the fuel lines in the engine, see illustration 95, that could be switched on with the help of a battery if the engine for some reason stops working. The installation of the heating tape was introduced in previous chapter 5.4.2.1 called Installation instructions. (Raychem , 2012)

Illustration 96.- Engines fuel lines

HEATING PAD

As for the heating pad would be installed under the engine's oil tank, which would also help the motor to start more smoothly in colder weather. When the engine is started the heated up oil will move inside the motor and heat it up. The heating pad model 16, illustration 96, that would be used is sold by a company named Wolverine Heaters. The pads technical specs can be seen in the table 18 below.

Illustration 97.- Wolverine heating pad Model 16

Model 16
11,3x9,0 cm
250 W
240V
77 USD

Table 18.- Technical specs over the heating pad Model 16

With the help of the technical spec, it can be calculated that the heating pad could run constantly 5h and 30 min if there would be used a 12 VDC battery while using a 240 V inverter.

Installing the heating pad is easy. Firstly, all the surface of the oil-tank has to be cleaned from dirt, grease or oil. After that the surface is cleaned, plug in the pad for 3 to 5 seconds to warm up the adhesive. This will help the glue to stick more easily. If the pad is plugged in longer than a few seconds it may burn exposed skin or damage the heater. But before applying the pad to its place unplug it and avoid wrinkles or creases while pressing down the pad. After this attach the AC cord with a cord tie to prevent the weight of the core from pulling down the heating pad. When this is done put on the heater for 5 to 10 seconds and turn it off while squeezing the pad. This can be done twice and lastly apply the high temperature silicone adhesive around the edges and be very careful that the silicone doesn't end up under the heating pad because this keeps the pad weatherproof. After that the heating pad has been installed secure the route and the rest of the AC cord to a conventional place. Another important thing to remember is not to use the heater for 24 hours after the installation. (Wolverine Heaters, 2015)

REASONS FOR THE SOLUTION

The reason these solutions were chosen was that they are easy to implement and economically feasible. To save costs there is the possibility to use the same heating tape on the engine as on the fuel lines. Then it is possible to use the same sensors for the whole heating solution. Here it's possible to choose if only heating tapes are going to be used, this would not be beneficial in the end though, since it would not heat up the engine as effectively as a combination of the two different solutions.

The heating pad is a good alternative since it is possible to choose when to use it, if you only want to activate it on a cold day before starting the engine for example. Same when using in cars it helps to heat up the engine oil before starting the engine.

The whole system would require 490 W with a 12 V battery and with an inverter it could be in constant use for 2 hours and 40 minutes.

I = P/U à 490 W/ (12 V* 1,1) = 37,12 A

C = I*t à 100 Ah / A = 2,7 hours on constant use

These two solutions would have a total cost of 140€. The costs increase of course if another battery and inverter is wanted. Then total cost would be about 230€.

5.7. AUTOMATION OF THE SOLUTION

For the final solution, an Arduino programmable card is the best option. It is highly reliable, simple, cheap, easy to replace and easy to adapt to the environment. The card will be placed in a waterproof box under the boat's command table.

Even is the components are not exactly the same, the sequence that will be followed by the card will be very similar to the one of the pressurized bag solution.

It is necessary to have a special attention to the end of the fishing trip, when the engine will be turned off. The pipes inside the engine are very difficult to warm if the engine is off, that is why it is essential to not have any presence of biodiesel in the circuits at this moment. In order to prevent this problem it is always necessary to wash the circuit with diesel before turning off the engine. It might not be possible to start the engine if the pipes are full of viscous biodiesel. The washing will have to be done when the fisherman wants to stop the engine during a long time in cold temperature or when he comes back to the harbour.

There are different methods to automatize the washing of the pipes using different factors:

- **Depth:** it is possible to use the sonar of the boat to switch the fuel when the depth decreases at a certain point (10-20 meters for example). This means that the boat is getting closer to the harbour. Even if this solution seems random it is really interesting because the diesel will be only used as long as the boat is next to the coast.

- **GPS:** by adding a simple GPS module on the Arduino, it is possible to localise the harbour. When the position of the boat reach a limit perimeter around the harbour, the Arduino switch the fuel to wash the pipes. On the illustration 97 is an example with the Björköby's harbour and a 3.5 kilometers diameter perimeter around it. As long as the boat will be inside the red circle, it will use diesel. If it cross it, the fuel is

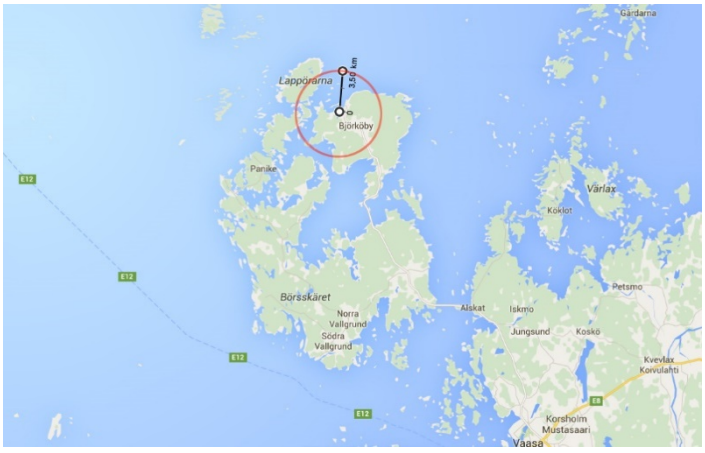


Illustration 98.- Map with a perimeter around the local harbour of Björköby

switched to biodiesel. It is also possible to add several harbour's locations with different perimeters.

- **Hour:** if the fisherman uses to come back around the same, hour, it is possible to switch the fuel after a fixed hour. But this solution is too restrictive and cannot be used for the system.

- **Speed:** the Arduino can also switch the fuel at a certain speed. If the boat reduces it speed, it might mean that the harbour is close or that the fisherman will do a break. For example below 5 knots (9.3 km/h) the used fuel could be diesel and above 5 knots biodiesel.

- **Manual:** a manual solution would be the best one if the fisherman never forget to switch the fuel when he comes to the harbour. But it will be an unpleasant loss of time and fuel if he forgets to press the switch button.
- **Turning off the engine:** when the command to turn off the engine is made, the fuels are switched and the engine continue running a few time without and gear engage to clean the pipes. This idea is good because it is very reliable, but it is also a big loss of time and fuel.

In the end the final sequence that the Arduino will follow has been chosen according to a study of all the different possibilities of utilisation and all the issues that might happen.

The card will be equipped with a GPS module that offers it the possibility to track its position in real time. This module illustration 98 cost around 15-20€ and is inserted on the main card. When the card enters in the harbour area, it will emit a signal to the fisherman (DEL light button + buzzer) in order to make him remember to switch the fuel. The sound only occur when the boat cross the perimeter but as long as it is inside, the light will stay on. The fisherman always has to switch the fuel for a security reason and because he might just cross an area but not come to the harbour. The GPS is a help but it do not replace the fisherman.
The thermic sensors are little water proof probes that can be placed inside the fuel tank or on a pipe. If the sensors is on a pipe, it will be fixed with a heat conductor metal illustration 99.

Illustration 99.- GPS module on Arduino UNO : www.lextronic.fr

Illustration 100.- Waterproof temperature probe : www.thermistor.com

The program that will be loaded in the Arduino will work following this sequence:**Green:** User action // **Blue:** Arduino action // **Red:** Sensors, GPS, and other information

- Start the engine
  Get the biodiesel tank temperature, is it >30°c?
  - Yes: Switch to Biodiesel reset and stop timer
  - No: wait
    ↳ Timer on? Yes: do nothing / No: Start timer

- Get GPS location (entering in a perimeter?)
  - Yes: Buzzer + light button
  - No: wait

- Switch button
  If biodiesel is in use, switch to diesel and start timer
  If diesel is in use, get the biodiesel tank temperature, is it >30°c?
  - Yes: Switch to Biodiesel reset and stop timer

- No: wait

- Shut down the engine
  Biodiesel in use?
  - Yes: Switch to diesel and start timer
  - No: timer > 120 seconds?
    - Yes: Shut down the engine
    - No: Wait

- Get filter sensor temperature, it it 30°c?
  - Yes: Switch off the filter warming blanket
  - No: Switch on the filter warming blanket

- Get fuel line sensor temperature, it it 30°c?
  - Yes: Switch off the fuel line blanket
  - No: Switch on the fuel line blanket

- Biodiesel in use?
  - Yes: Biodiesel light on
  - No: Diesel light on

All the different parts above are working simultaneously and continuously. It means that the card always track its location, always check at the temperatures and is ready to switch in the same time.

In case of emergency a special system has been designed in order to start the engine even if viscous biodiesel in the pipes. If the engine has a failure during a long time when the boat is in the middle of the sea then the pipes will not be washed. For this reason a special blanket will be added on the pipes that go to the injectors. If the fisherman has an issue during a trip, he will be able to push a button that will start the warming of all the blankets, following this additional sequence.

- Emergency warming button
  Engine On?
  - Yes: do nothing
  - No: Warm all the blankets until T°>30°c
    Switch to diesel
    Start the engine

Then when the temperature in the biodiesel tank reaches 30°c again, the system will automatically switch the fuel again.

This system is the most efficient in order to save money and it is also the most secure one. The Arduino card can easily be changed if necessary and if it suddenly stop working (extremely low probability) it is still possible to switch the valves manually.

On the control board, the fisherman will have several command button and indicators

- The switch button : to switch the fuels at any moment
- The start / turn off button
- Emergency warming button
- 2 DEL that will inform him about which fuel is actually in use

- A buzzer and a DEL that will remind him to switch the fuel when he get close to the arbour

It is also possible to install a screen on the control board (Illustration 100) which can indicate the temperatures, the state of the valves and also the GPS position and the perimeters. We can also think about adding a system to allow the fisherman to manage the perimeters with a graphic interface.

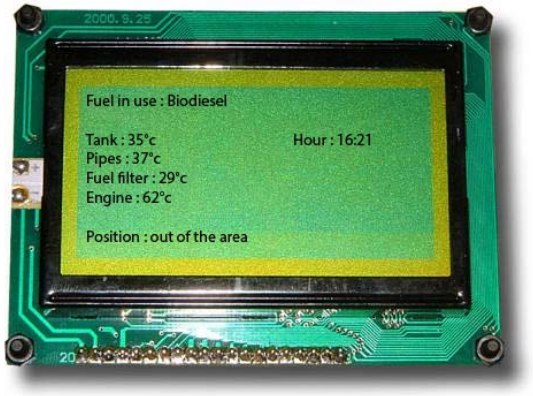


Illustration 101.- Example of an Arduino connectable screen

5.8. ECONOMIC STUDY

The team has visited several fishermen in the Ostrobothnia region. The most important thing that was learned from these trips is the difference between all the boats. The specifics of the boat that will impact the solution are the amount of fuel lines in meters, the tank size and the size of the engine.

In order to make a well-founded estimation of the total cost of the product it's important to make a different estimate for the different size of boats. There will be an estimation for a small boat and one for a big boat. This means that all other boats will be, in theory, in between these two boats.

Research that can be found earlier in this report has shown that more than 95% of the fishing boats are larger than 7 meter and smaller than 12m. This sizes will be used to determine the price for a small and a large boat. The numbers in the table below are based on observations and estimations.

	Small boat (7m)	Large boat (12m)
Fuel lines in meter	2	4
Fuel capacity main tank	100	300
Use of fuel in Liter a day	35	70

Table 19.- Information about the different boats

According to these estimations and the price of all the components of the system (appendix), it is possible to predict the amount of money that will be saved across the years. The return on investment will depend on the fisherman habits, his hours of work every day and the maintenance cost.

The life cycle of all the components has been estimated according to the manufacturer data and with a security coefficient. For this reason, there are no additional expectable costs in the predictions.

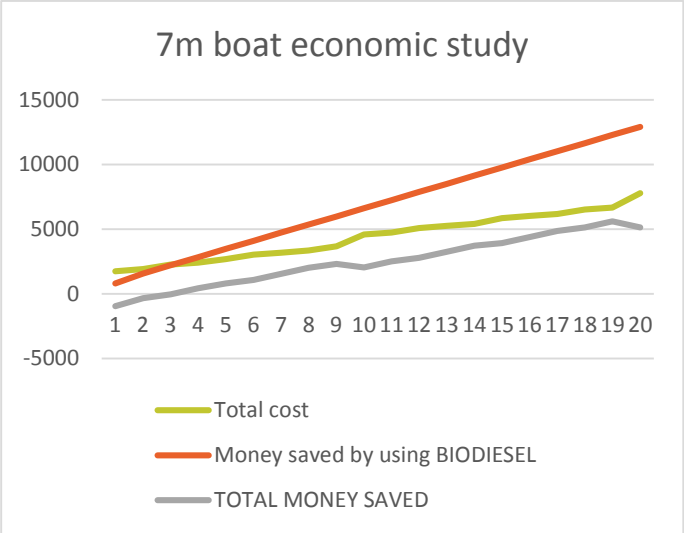
Statement from interview and researches; a fisherman works during an average of:

- 8 months/year
- 8 hours/day → 7 hours/day using biodiesel
- 15 days/month

Considering that with FEORA it is possible to save 0.15€/litter of fuel when the fisherman uses biodiesel it is expected to save about 790€/year for a small boat and 1260€/year for a big one.

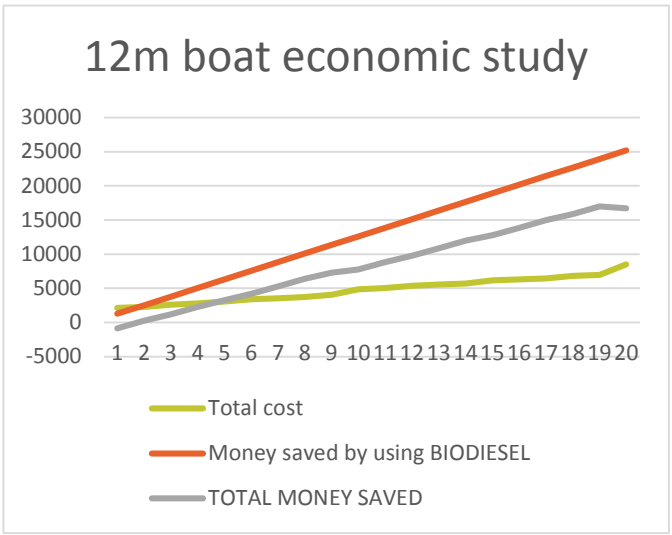
The price of the system will also depend of the size of the boat but the variation is small because only few parts will change. The price of the cables, isolation, line heater,… will change but it will still use 2 valves, one filter heater, and the same automation system.

Here are the graphs that shows the evolution of the money spent, and the time before return on investment (all the data are in the appendix 4).



Graph 20.- 7m boat economic study

The green curve represent the cost of our system including the maintenance. The grey one represent the real wallet of the fisherman. For this kind of boat the grey line reach the 0 after 3 years which means that during the 3 first years the fisherman will lose money but then he will start save it. In this case the return on investment will happen after 3 years and after 20 years of utilization the fisherman will have saved around 5130€.



Graph 21.- 12m boat economic study

For the 12m boat, the return on investment is faster, only 2 years. Furthermore as the boat consume more fuel, the biodiesel will save more money. After 20 years of utilization the fisherman will have saved around 16700€.

This study does not include the installation cost because it is impossible to predict it for now. Also these data are based on estimation made according to our sources and interview, they also might change.

6. CONCLUSION

6.1.THE PROJECT

The final function of this system is making usage of biodiesel in the fishing industry possible, but the solution provided in this report can only be seen as a concept and needs further work to be realised.

The implementation of the ideas, solutions and designs shown in this report will make the fishing boat more efficient, cleaner and cheaper. As it has been exposed in this work, the numbers of the fishing industry in Finland are decreasing, less people every year is working as a professional fisherman and the money coming from the fishing industry is diminishing. On the other hand the usage of biodiesel is becoming more popular worldwide, its production is growing fast and its price will be cheaper than conventional fuels. So, the advantages that the biofuel offers to fishermen and the environment are a perfect reason to start using biodiesel.

During the research part of this project, three issues were found to be the limitation factor to use biodiesel in cold climates. Therefore, it was important to eliminate these issues by finding solutions and make it work in the already existing system on the boats.

This ended up in a system were influences from outside are accounted for as much as possible. The concept is developed with the goal in mind to make it a reliable and a relatively cheap option for the fishermen. For information purposes a booklet is made and a website is provided with all kinds of additional information about the project, trips and our team.

6.2.THE PROCESS

The Project started off with the research phase, were every team member was assigned his own research topic. When the research was completed all the issues were stated in the conclusion to get to work for finding a solution for these issues.

It is important to say that the "field work" in different harbors interviewing fishermen was an extremely helpful tool, it got us closer to the fishing industry and since that moment we felt more involved on our project, feeling more motivated to achieve the goals.

Once the scope was determined the team did some brainstorming, both individual and in group. This resulted in numerous ideas and systems, which were put together in order to create the first stage of a concept. After these numerous solutions were found, it was time to make a decision on which final solutions would be used. This was followed up by making a detailed description of the chosen solutions. When the different solutions were described, they were adjusted to work together in a system and checked for economic possibility.

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8. APPENDIX

1.- PRESSURIZED BAG SOLUTION'S PROGRAM

```
void setup()
{
  pinMode(1, OUTPUT);                    //biodiesel valve
  pinMode(2, OUTPUT);              //diesel valve
  pinMode(3, OUTPUT);                    //air valve
  pinMode(4, OUTPUT);                    //air pump
  pinMode(5, OUTPUT);              //engine

  pinMode(6, INPUT);               //engine start button
}
int main()
{
  int T_biodiesel;
  int start_button = 0;            //engine start button state
  bool engine_state = 0;                 //0=off 1=on
  while (1)
  {
    start_button = digitalRead(6);                  //the same number as "pinMode(..., INPUT)"
    T_biodiesel = analogRead(A0);                   //read sensor
    T_biodiesel = map(T_biodiesel, 0, 1023, -20, 90);               //convert to temperature

    if (start_button == 1 && engine_state == 0)
    {
      engine_state = 1;              //"on"
      pinMode(5, HIGH);              //starting the engine
    }
     if (start_button == 0 && engine_state == 1)
    {

      digitalWrite(1, LOW);          //close biodiesel valve
      digitalWrite(2, HIGH);         //open diesel valve
      digitalWrite(3, HIGH);         //open air pump valve
      digitalWrite(4, HIGH);         //start air pump

      delay(10000);                  //waiting 10000ms
      engine_state=0;                //"off"
      pinMode(5, LOW);               // shutting down the engine

    }
    if (engine_state == 1)
    {
      if (T_biodiesel >= 20)
      {
```

```
      digitalWrite(1, HIGH);        //open biodiesel valve
      digitalWrite(2, LOW);         //close diesel valve
      digitalWrite(3, HIGH);        //open air pump valve
      digitalWrite(4, HIGH);       //start air pump
    }
    else
    {
      digitalWrite(1, LOW);         //close biodiesel valve
      digitalWrite(2, HIGH);        //open diesel valve
      digitalWrite(3, HIGH);       //open air pump valve
      digitalWrite(4, HIGH);       //start air pump
    }
   }
  }
}
```

2.- WATERPROOF TEMPERATURE SENSOR SPECIFICATIONS

Illustration 102.- Waterproof temperature sensor DS18B20

Specifications

Resolution adjustable	9 to 12bits
Operating temperature	-55 °C to +125 °C
Power supply range	3V to 5.5V
Code	Red (+ power supply.), Black (ground) Yellow (Data)
Cable length	100cm
Stainless steel tube size	6x45mm
Technical name	DS18B20
Webpage and reference	http://www.selectronic.fr/sonde-de-temperature-waterproof-ds18b20.html# *Ref. 3006-800*
Price	**5,45 €**

3.- AIR BREATHER SPECIFICATIONS

Model X-121

Illustration 903.- Air breather specifications

Price : 180€

Source: *http://www.airsentry.com/*

Product Specifications	
Check Valve PSI In/Out:	0.1/2.0
Height (in):	7
Height (cm):	17.8
Diameter (in):	5
Diameter (cm):	12.7
Both Ends Connection:	n/a
Mounting Connection:	2" MNPT
Silica Gel (lbs):	1.4
Silica Gel (kg):	0.6
Maximum Adsorption Capacity (oz):	8.6
Maximum Adsorption Capacity (ml):	254
Maximum Air Flow (cfm):	20
Maximum Reservoir Fluid Flow (gpm):	150
Type of Medium:	100% Silica Gel

4.- ECONOMIC STUDY OF THE SOLUTION

7m boat

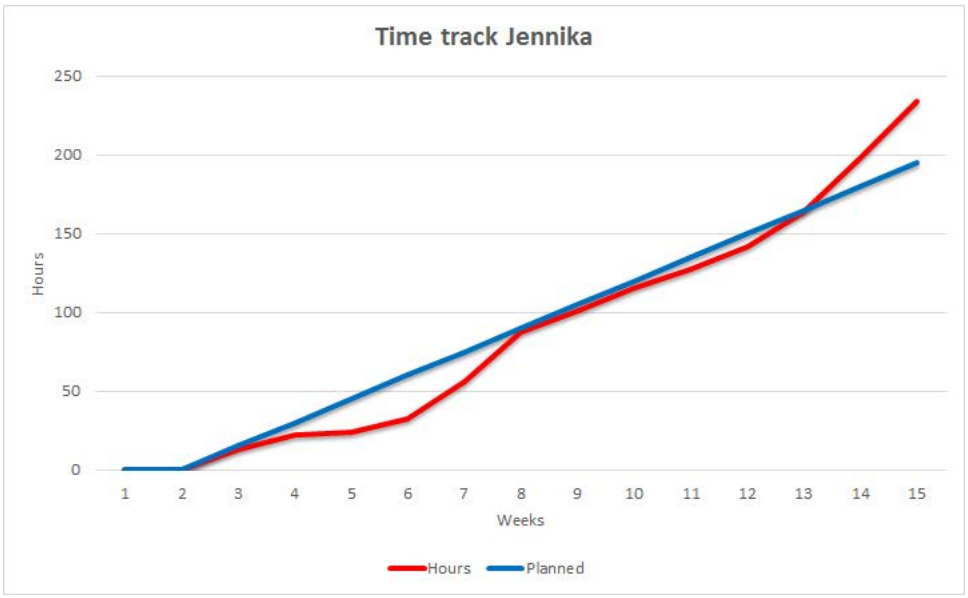
Part	Average price small boat	Average Price big boat	Replaced after	Source
1 Tank dryer	24 €	24 €	3 months	http://www.ikalog.fi/app.php?RelId=6.4.7.7&BookCode=fin14flx&Pag
12 tank dryers	240 €	240 €	3 months	same source above, is comming from a finish source
Insulation lines and tank	€ 80	€ 165	20	http://www.pipelagging.com/
Diesel tank	80 €	150	never	http://tektankslimited.com/96-litre-fuel-tank-tt-5649-1100-x-400-x-28
Arduino UNO card	20	20	20	http://boutique.semageek.com/
Arduino module	15	15	20	http://www.lextronic.fr/P5910-platine-shield-gps-pour-arduino.html
Electrovalve (100€*2)	200 €	200 €	20	http://www.conrad.fr/
Cables 0.3€/m	24	48	10	http://www.conrad.fr/
Arduino waterproof case	5	5	20	http://www.gotronic.fr/cat-boitiers-etanches-1278.htm
Arduino screen	22	22	20	http://boutique.semageek.com/fr/204-ecran-tft-lcd-177-spi-arduino-8
DEL + buzzer	1	1	20	http://www.conrad.fr/
Waterproof temperature sensor	5,45€ x 4 = 21,8€	21,8	10	Appendix 2 of the final report
Air breather	180 €	180 €	3	Appendix 3 of the final report
Cartridge for air breather	15	15	4 months	Company contact + average with concurence
Aluminum heater exchanger biodiesel tank	240 €	240	20	http://es.aliexpress.com/item/B5-volkswagen-passat-heater-tank-dri
Biodiesel aluminum tank 300L	150 €	300	never	
Heating patch for filter	55	€ 60	10	http://www.utahbiodieselsupply.com/fuelfilterheater.php
Silicone insulation tape	2	2	10	http://www.alphamultiservicesinc.com/page/447239620
Silicone tape for fuel lines	€ 140	280 €	10	http://www.alphamultiservicesinc.com/page/447239620
coolant filter mount	36	36	20	http://www.utahbiodieselsupply.com/fuelfilterheater.php
battery	169	169	10	http://www.batterystuff.com/batteries/rv-marine/
Heating pad	77	77	5	https://www.wolverineheater.com/Marine-s/1514.htm
Heating cable	70	70	10	https://www.traceheatinguk.co.uk/raychem-20xtv2-ct-t2?cat=1974
battery	160	160	10	http://www.atbatt.com/sealed-lead-acid-batteries/b/power-sonic/m/
inverter	31	31	5	http://www.amazon.com/Rally-7559-Volt-Watt-Inverter/dp/B005JBVA

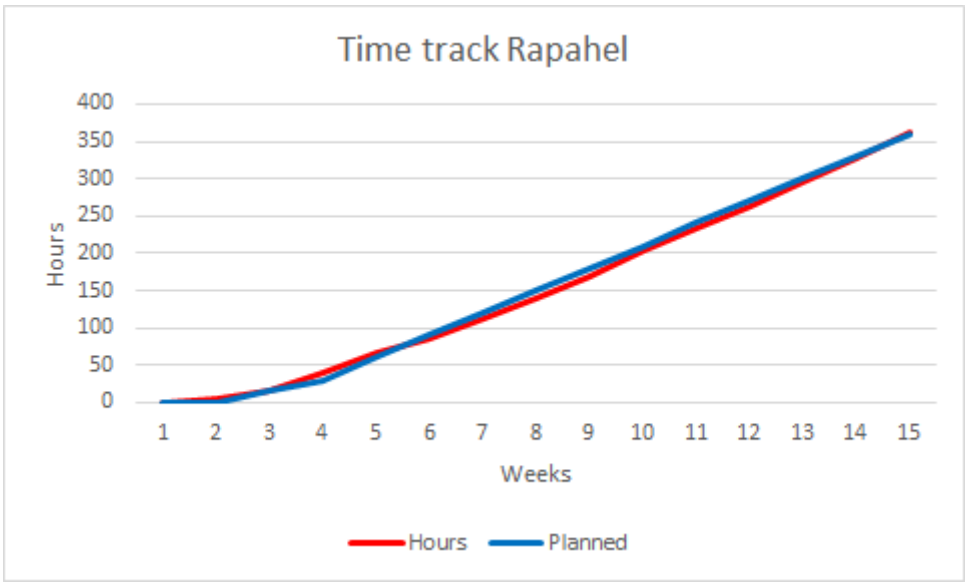
Year	Cost	Total cost	Money saved by using BIODIESEL	TOTAL MONEY SAVED
1	1749	1749	787.5	-961.5
2	160	1909	1575	-334
3	340	2249	2205	-44
4	160	2409	2835	426
5	268	2677	3465	788
6	340	3017	4095	1078
7	160	3177	4725	1548
8	160	3337	5355	2018
9	340	3677	5985	2308
10	910	4586.8	6615	2028.2
11	160	4746.8	7245	2498.2
12	340	5086.8	7875	2788.2
13	160	5246.8	8505	3258.2
14	160	5406.8	9135	3728.2
15	448	5854.8	9765	3910.2
16	160	6014.8	10395	4380.2
17	160	6174.8	11025	4850.2
18	340	6514.8	11655	5140.2
19	160	6674.8	12285	5610.2
20	1110	7784.6	12915	5130.4

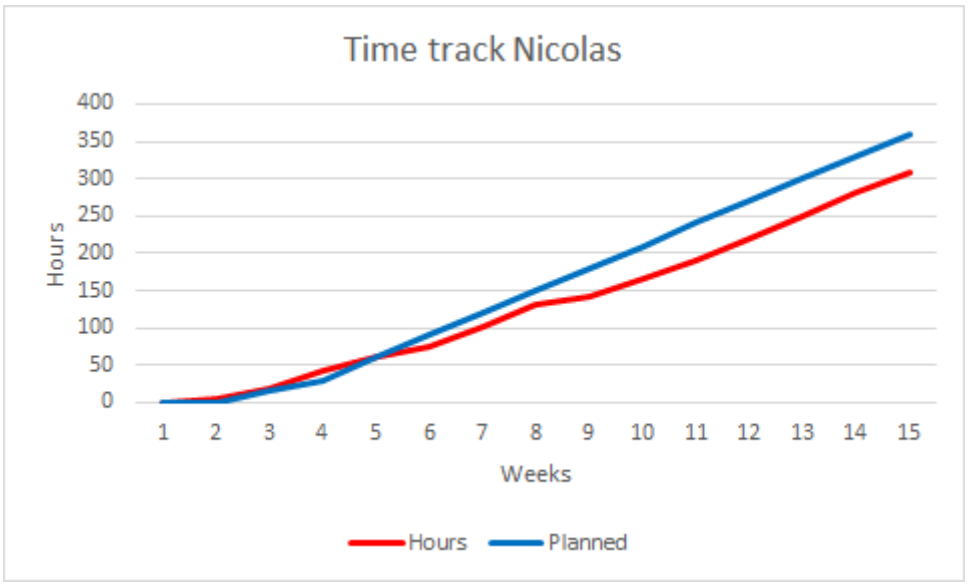
12m boat

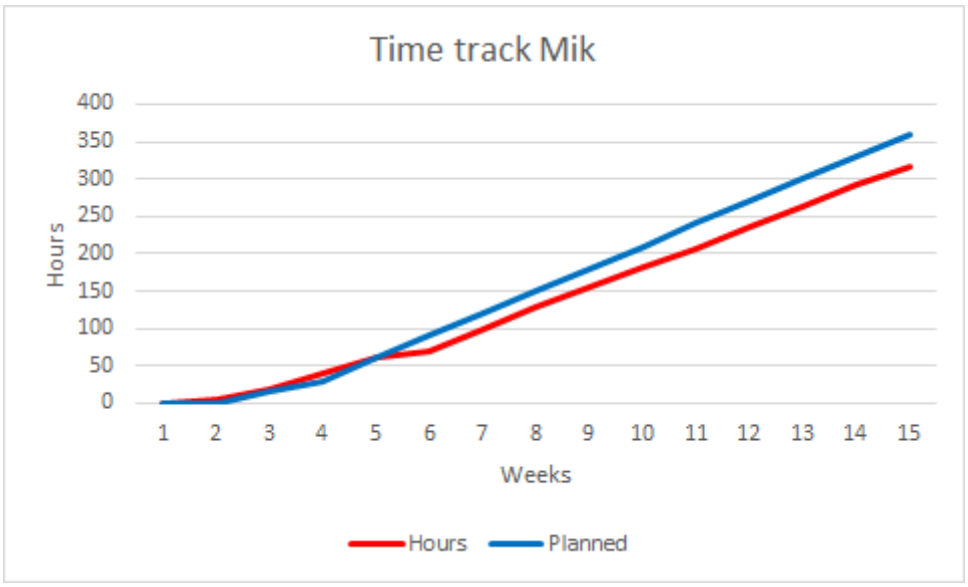
Year	Cost	Total cost	Money saved by using BIODIESEL	TOTAL MONEY SAVED
1	2113	2113	1260	-853
2	160	2273	2520	247
3	340	2613	3780	1167
4	160	2773	5040	2267
5	268	3041	6300	3259
6	340	3381	7560	4179
7	160	3541	8820	5279
8	160	3701	10080	6379
9	340	4041	11340	7299
10	827	4867.8	12600	7732.2
11	160	5027.8	13860	8832.2
12	340	5367.8	15120	9752.2
13	160	5527.8	16380	10852.2
14	160	5687.8	17640	11952.2
15	448	6135.8	18900	12764.2
16	160	6295.8	20160	13864.2
17	160	6455.8	21420	14964.2
18	340	6795.8	22680	15884.2
19	160	6955.8	23940	16984.2
20	1531	8486.8	25200	16713.2

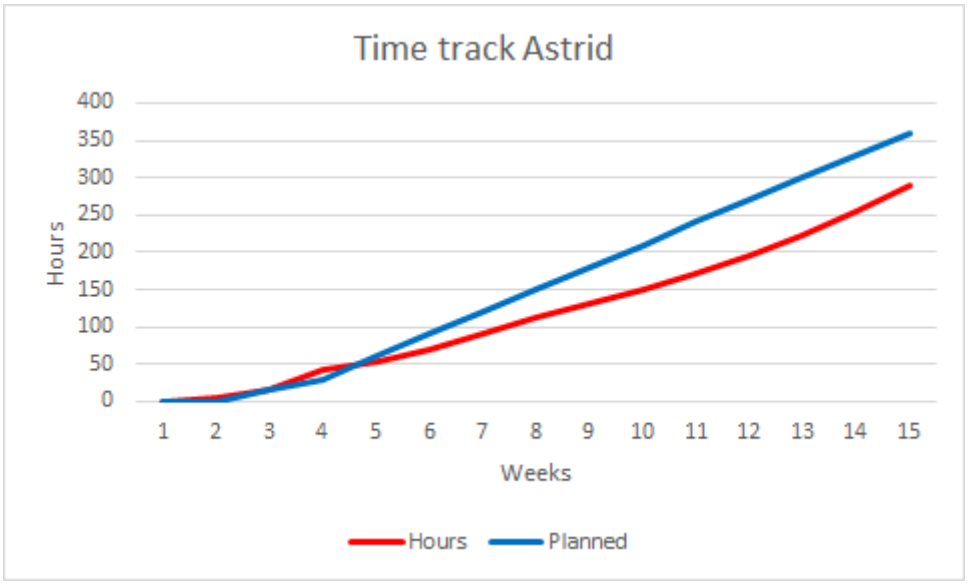
Time tracking of the team


Time track Jennika
250
200
150
100
50
0
Hours
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Weeks
Hours
Planned


Time track Rapahel
400
350
300
250
200
150
100
50
0
Hours
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Weeks
Hours
Planned


Time track Nicolas
400
350
300
250
200
150
100
50
0
Hours
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Weeks
Hours
Planned





5.- INFORMATIVE BOOKLET (THREEFOLD FLYER)

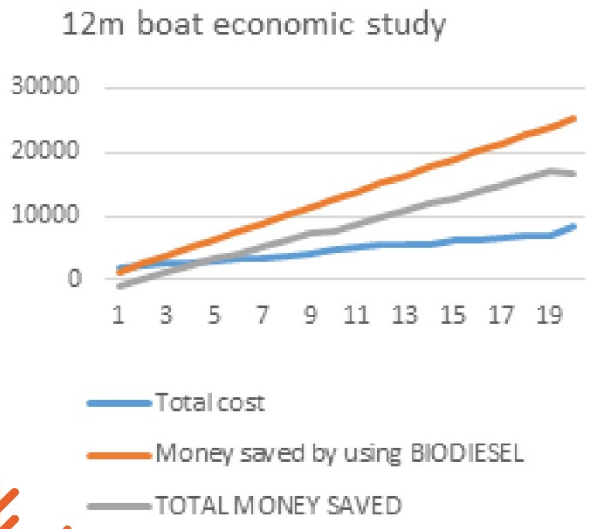
The booklet serves as an informative tool for possible costumers and interested parties. It contains the most important information to get to know both Fibiod and their product. The flyer is printed on a single paper and folded lyke a threefold flyer.

Economic reasons

Our system will allow the fisherman to use biodiesel in any season. Biodiesel is cheaper than diesel by 0.15€/L according to Feora oy prices. Fishermen use approximately 8400 litres of fuel each year, if this fuel was biodiesel it would create a saving around €1260 each year.

Even if the fisherman consume less, the financial and ecological gain is still worth the effort.

According to the price of our solution, the return on investment will only take one to two years. After this a lot of money can be saved.



For who is it?

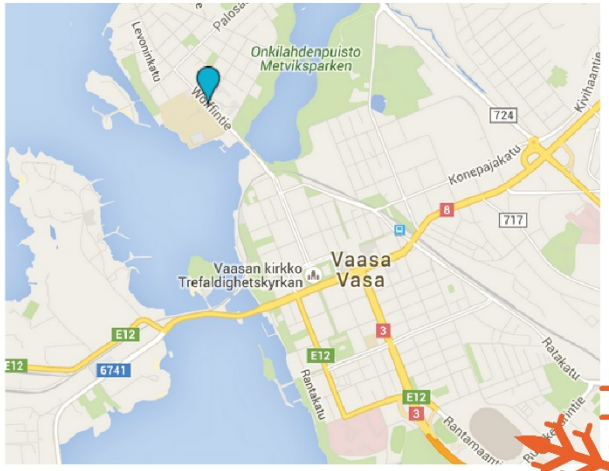
This project concerns any professional fisherman. It can be applied to any type and size of boat as long as it uses a diesel engine. The system needs access to the fuel lines, the cooling lines and the engine to be implemented in the boat. Then Fibiod will create a personalized program according to the fisherman's location and wishes.

How to order?

If you'd like to order the system, you will need to contact us firstfor a preliminary visit. If your boat is eligible for the solution, a custom made program will be implemented on the software with the location of your harbours.

Are you interested or just curious?

Contact us on
https://fibiod.wordpress.com/contact-us/



Using biodiesel in cold climates

YRKESHÖGSKOLAN
NOVIA

What is Fibiod?

Fibiod is a project by a group of students who participated in a European Project Semester.

This semester promotes collaboration between students from all over Europe.

We are a team of five students from different countries and a different scholar background working together at Novia University of Applied Sciences in Vaasa, Finland. Our goal is simple, work on a project together and use our different skills to produce something better than expected and improve our personal English skills and our cultural knowledge about other countries.

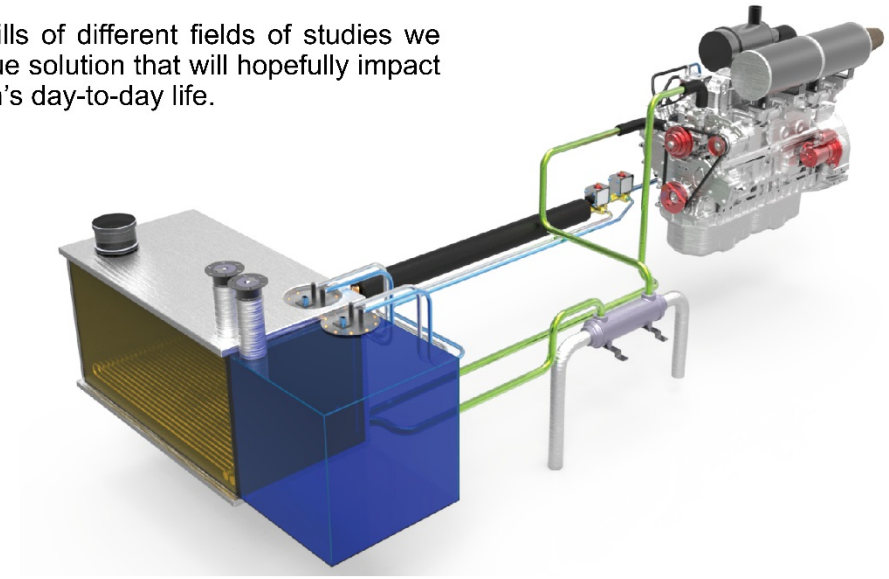
"The goal of this Fibiod project is to make it possible to use biodiesel in cold climates such as in Finland."

The solution

The result of the project is a system that uses biodiesel safely in every climate and reduces the cost and the environmental impact. The system will warm the biodiesel to make it flow better. When the right viscosity is reached the fisherman can switch from diesel to biodiesel. This switch will happen automatically in order to give you an easy, cleaner and cheaper fishing experience.

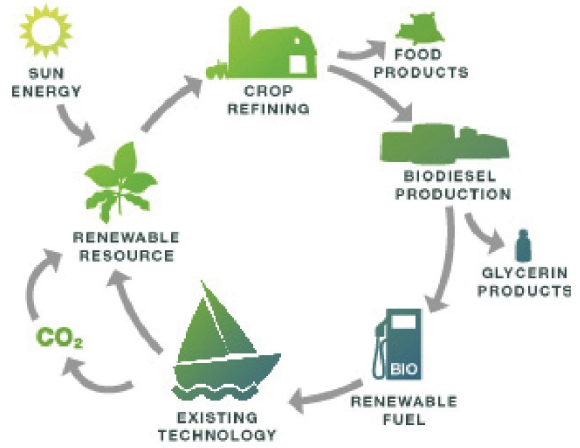
The system will be adapted to the type of boat and will use both diesel and biodiesel. The biodiesel tank and fuel filter will be heated with coolant water since this is basically a free source of heat. The fuel lines are electrically warmed. All this will prevent the biodiesel clogging. A safety system on the engine can heat the engine lines if necessary to prevent clogging. These steps will all happen automatically thanks to the included Arduino card. This software will also automatically flush the engine with diesel at the end of the trip to purge all the biodiesel from the fuel system.

Using the skills of different fields of studies we made a unique solution that will hopefully impact the fishermen's day-to-day life.



Why using biofuel?

Last years the price of fuel has been rising sharply, this means that fishing has become more and more expensive. Biodiesel is not only cleaner than normal diesel, it is also cheaper. Unlike normal diesel, biodiesel takes part in a closed cycle which re-uses the CO2 emitted by the combustion of the fuel to grow seeds.



These biofuels can also be produced from by-products of the fur industry, these can be recycled instead of being thrown in the trash.

A reliable and cheap system

The solution that we propose is easy to install and to replace. It is made of standardized components massively present in the market and thereby easy to order and affordable. It uses two different fuels in order to adapt itself to the situation and it also includes a fuel safe mode in case of engine failure. Furthermore the fisherman will always have the power to control everything manually in order to have a maximum security.