LNG Transportation Miniature Model

Final Report

Project team: Arno Van Dyck

Bétina Salmon

Carineke Post

Coordinator: Andreas Gammalgård

Date: 16 May 2017

Institution: Novia University of Applied Sciences

Semester: EPS Spring 2017

Summary

This report is containing the progress of the LNG miniature model project. This project is conducted for the European Project Semester at Novia University of Applied Sciences. The project is about building a miniature model, which is explaining the transportation chain of liquid natural gas. Liquid natural gas is the liquid phase of natural gas. Using liquid natural gas might be an option for Finland to investigate and this model can be used to teach students about the transportation chain. All the production steps are included in the model. The model is made interactive by using buttons that correspond with LEDs and LCD screens. The LCD screens shown text which is explaining the theory behind each process step. A 3D printer was used to print models of the equipment. The miniature model is built over a time snap of sixteen weeks. The model is ready to use and can be found in Technobotnia, Vaasa on the second floor.

Acknowledgement

During our project we had several technical problems. Luckily we had several fellow students and teachers who helped us when needed and got us the result we wanted to achieve.

First of all we would like to thank our supervisor Andreas Gammelgård. During the course of our project he followed up all the work and gave us tips and his vision about the project.

Because the team had no knowledge in 3D printing the Fablab supervisors, Rayko Toshev and Osku Hirvonen helped us to get going. When prints did not turn out as expected Rayko gave some tips what to try in order to get the result we wanted.

Hans Linden helped us choosing the right electrical components and bought them for us. He also helped us with his expertise when we had to choose the right Arduino.

To build our project we needed a lot of tools and space. Markku Kuusinen gave us the option to use the metal lab as working space and we would like to thank him for that.

Olav Nilsson also had an important part in our project as he bought the wooden board and helped us to cut it in the right dimensions.

Roger Nylund is also a key person for our project as he coordinated the EPS schedule and make this project possible.

Finally we thank some of our fellow students for their advice and testing the model. One student in particular, Dries Peeters, got us going with the programming as he had prior knowledge and work experience with programming an Arduino.

Table of content

1. Introduction

This is the final report of an European Project Semester (EPS) project at the Novia University of Applied Sciences. This final report contains all the information on the project. The project is about building a miniature model of the transportation chain of Liquid Natural Gas (LNG). In this report the final results can be found, together with the designing journey, information on the project team, a summary on the project management, the theoretical background of the project and the test results.

1.1 European Project Semester

The European Project Semester is a program offered by seventeen different universities spread over Europe. It is a program which is mainly focussing on engineering students, but also students from other study fields could join the program. The program aims to create a realistic multidisciplinary environment to prepare students for the working life. It contains the project itself and several courses to support the project. The courses are for example: project management, team building, intercultural communication, leadership and corporates social responsibility. Altogether, a student will gain 30 ECTS with the project semester. This EPS project is carried out at The Novia University of Applied Science located in Vaasa, Finland.

1.2 The project

This project is about the transportation chain of liquid natural gas (LNG). LNG is a form of natural gas, which is used to transport the natural gas to distant markets. The natural gas is cooled down to at least -162^{o}C to be in liquid state. The volume of liquid natural gas is 600 times as small as gaseous natural gas. The decrease in volume makes the transportation easier, especially over long distances. Finland does not have any gas sources and because natural gas is the cleanest fossil energy source it could be a good option for Finland to use LNG. Natural gas is the cleanest fossil fuel, because during combustion no sulphur or heavy metals emissions are created. The transportation of LNG is still not widely used in Finland and still a lot of research is being done. In this project the options of the transportation are discussed and shown in a miniature model. The miniature model will be created to inform students about the way the transportation can be done. The miniature should be interactive and attractive for the students.

1.3 Overview of the report

The report will start with introducing the project team and the identity of the project team. This includes the results of a Belbin questionnaire each team member did, the designing of the logo of the project team and a description of the project website.

Secondly, a summary of the project management will be given. The total project management part can be found in de midterm report. This is not included in this final report, because it was chosen to focus on the end results and the information needed to understand the miniature model.

After the project management, the results of the literature research will be discussed, followed by the designing of the real model. A description of the assembling will be given and the report ends with the test that was held under students to see if the model meets the requirements.

2. Project Team and Project Identity

2.1 Team

The team working on this project consists of three students from different countries and with different educational backgrounds. The goal of working in such a team is to develop intercultural communication skills and interpersonal skills. All team members are taking responsibilities while participating in the project. The team has the responsibility of making a complete model, where an excellent understanding of the functioning of the entity is essential. This project is an opportunity to apply scientific reasoning on multidisciplinary subjects and more particularly to test the team spirit. Obtaining quality work uses criteria such as good relationships and a high degree of adaptability within a team.

CARINEKE POST

Country:	The Netherlands
University:	The Hague University of Applied Sciences
Course:	Process and Food technology (Chemical Engineering)
Email-address:	carinekepost@gmail.com
Specialisation in the project:	Chemical theory of LNG and writing skills

ARNO VAN DYCK

Country:	Belgium
University:	University of Antwerp
Course:	Industrial Engineering
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Specialisation in the project:	3D modelling and 3D printing

BETINA SALMON

Country:	France
University:	Polytech Marseille

Course:	Ingénieur en Microélectronique et Télécommunication
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Specialisation in the project:	Electrical work

2.2 Belbin questionnaire

Persons working in a project group can play a different role in the group. When the group is aware of the role of each person, it would be easier to respect and to approach each other. The Belbin test can be used to investigate which role each team member is playing. The Belbin questionnaire is based on eight different team roles. Before showing what team roles these team members are having, the eight different team roles will be explained shortly (Belbin, 2017).

- **Resource Investigator:** This team member is using their inquisitive nature to find ideas. This makes them capable of exploring opportunities and developing contacts. This member is outgoing and enthusiastic, but when the initial enthusiasm is fade away this member can lose the interest in the project.
- **Team worker:** This team member is using its listening skills, its co-operative, perceptive and diplomatic personality to help the team to gel. This member can easily identify what work is required and will complete it on behalf of the team. This member tends to avoid confrontation and can be indecisive in tough situation.
- **Co-ordinator:** The co-ordinator is focussing on the objectives of the team. This member is delegating the work and is drawing out team members. The person with this role is mature, confident and is identifying talent. It can happen that the co-ordinator is offloading their own share of the work.
- **Plant:** This member is using their creativity, imagination and free-thinking to generate ideas and to solve problems in unconventional ways. The creativity results in dreaming, which leads to being unable to communicate effectively.
- **Monitor:** A monitor is a sober, strategic and discerning person. The person is using these characteristics to make impartial judgements. The monitor is seeing all the options and is judging accurately. The personality can also lead to lacking the drive and ability to inspire others.
- **Shaper:** The shaper is adding the necessary drive to ensure the team stays moving, without losing focus or momentum. This member has the drive to overcome obstacles, but can also be seen as provocation.
- **Implementer:** This member is planning a workable strategy and wants to carrying this out as efficiently as possible. An implementer is turning ideas into actions and is organising the work that needs to be done. By planning the strategy, the implementer can be inflexible and can respond slowly to new possibilities.
- **Finisher:** The finisher is most effectively at the end of a project. This member is good in polishing and scrutinising the work for errors. The conscientious and perfectionism of this person can result in worry unduly.

A good project group should consist of a mixed group of those eight team roles.

2.3 Belbin results

The team members of this project group did the Belbin questionnaire. Each team member will discuss the results and will introduce themselves. At the end a small conclusion will be given.

2.3.1 Carineke Post

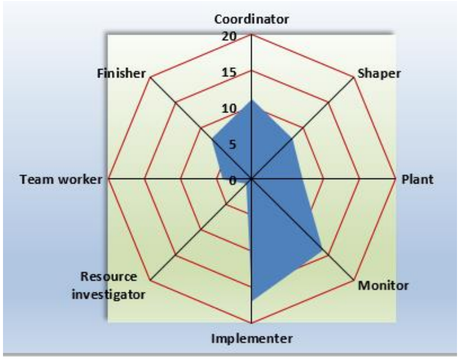


Figure 1 Result of Belbin test Carineke Post

I am Carineke Post and I am 21 years old. I grow up in Amersfoort, which is a city in the middle of The Netherlands. When I was 19 I started at The Hague University of Applied Science with the course Process and Food Technology, where I did my specialisation in Chemical engineering. Currently, I am in my final year, but I chose to do EPS before my graduation internship, which means I am postponing my graduation one semester. I already worked a lot with projects, so I already had an idea about which role I am playing in a team. This vision was confirmed by the Belbin test of which the result is shown in Figure 1 Result of Belbin test Carineke Post. As can been seen, I am mostly an implementer but also showing behaviour from a coordinator and a monitor. This means in a few words: I am disciplined, efficient, strategic and a good chairperson. Those characteristics come together with some weaknesses like inflexibility, lack of drive and ability to inspire others and somewhat manipulative. I agree with this characteristics because I know that I always want to go to the end of the project as fast and good as possible. This means I work disciplined and efficient, but it is hard for me to change paths, which makes me inflexible. During the meetings I had with previous project groups I was told that I am a really good chairperson, because I like to state ideas and deadlines clear. I do not have the ability to inspire others because I am too busy with finishing the project. I think it is a plus that I have good knowledge of my own skills and weaknesses so I can manage working in a project group in the right way.

2.3.2 Arno Van Dyck

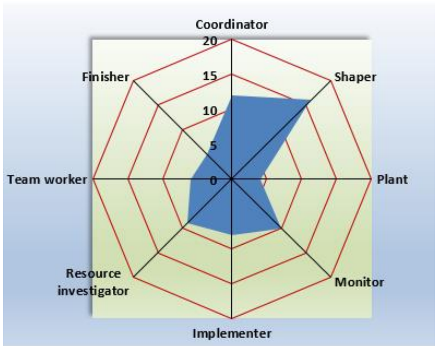


Figure 2 Belbin test result Arno van Dyck

Hey, my name is Arno Van Dyck and I am 21 years old. I come from a small city called Ekeren next to Antwerp, Belgium. Currently I am studying industrial engineering with a major in construction. To finalise my studies I am doing the EPS project in Vaasa, Finland. I chose the miniature LNG model because it is totally different from the skills I had to use during my studies and I want to learn as many new skills as possible. Filling in the Belbin test went surprisingly easy and fast for me. Some statements were spot on and received a lot of points where others totally did not match me and received zero points. If we look at the diagram in Figure 2 Belbin test result Arno van Dyck, then it can be conclude that I am mostly a shaper but also coordinator and monitor. If we look at my greatest strengths the team role explains we can see that I am a challenging, dynamic person who thrives on pressure. Also a delegating person who is mature and confident. I think this is a correct representation of my true identity and the way I behaved in previous projects. On the down side my weaknesses are that I can be seen as manipulative and sometimes hurting other persons feelings. As long as I focus on keeping these weaknesses small they should not stand in the way of progressive teamwork.

2.3.3 Bétina Salmon

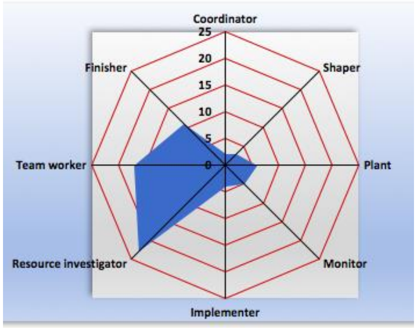


Figure 3 Belbin test result Bétina Salmon

Hi, my name is Bétina Salmon and I am 22-year-old student from France. I am studying Microelectronics and Telecommunication at the Polyptech Marseille (school of Advanced studies in Department Engineering). I chose to do an EPS in Finland to work on a project with other students from different nationalities to improve my English. I chose the project "LNG" because on the one hand I found it interesting to learn how such a process works and on the other hand it is the playful and technical side of the construction of a model that pushed me to choose this project. As can be seen in the results of my Belbin test, Figure 3 Belbin test result Bétina Salmon, it can be noticed that "resource investigator" result very evidently. Indeed, I have a very enthusiastic and communicative personality towards my teammates. I love human contacts, and it is very appreciable for me to create a relationship of trust with them. Nevertheless, having a concern to express myself in English, I remain much more discreet than if I could communicate in my native language. The fact of not being able to develop to the maximum my qualities of communications handicaps my team. In addition my second biggest trait of personality is "team worker", I like to work as a team, I work this exercise as soon as it is possible for me during my exam revisions or exercises of the life of all days like cooking, sports etc. I am very attentive to my teammates, perspective and diplomatic. I will be able to implement what I will be asked to do.

2.3.4 Conclusion on the team

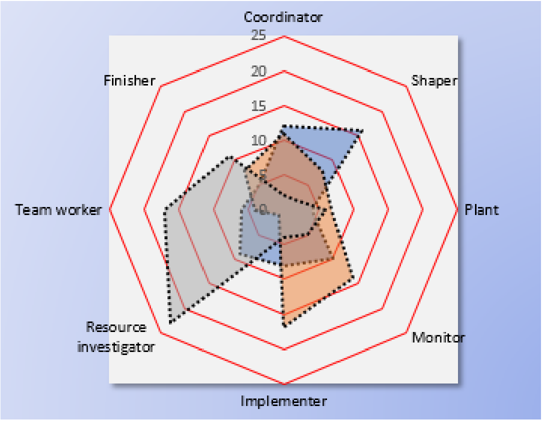


Figure 4 The three Belbin results combine in one diagram

By comparing our three Belbin questionnaires, we notice a great difference on the personalities. It can be notice that if the three diagrams are imposed, shown in Figure 4 The three Belbin results combine in one diagram, seven of the eight personalities are represented in our team. Carineke can use the experience she has gained from her previous years projects to avoid some unexpected mistakes. On the other hand, Carineke and Arno have the same skill over the performance of the tasks given, they are both leaders and have a natural tendency to lead. They will have to jointly build a common path and thus use good chairman strategies to distribute the tasks. But since they are disciplined and effective this should not be a problem. Bétina develops her relational skills and is able to adapt to others, she works with the others and she is questioning while maintaining a positive climate. She will not feel in any way manipulate by her two teammates of leader, because quite the contrary will motivate her. The Belbin profile of Arno shows that he will energise the team, which will be useful for Bétina who has a lack of confidence in her communication. It will then be necessary to use our complementarity of personalities to foster collaboration and to avoid the adoption of counterproductive behaviours. Furthermore, to share the same goal which is to finish in good condition with the best possible realisation of the model and our report. In conclusion, in a successful team, members understand and appreciate their differences and know that this is what makes them strong.

2.4 Logo and Name

Having an identity as project group is mandatory for an EPS project group. In the case of this project the logo will be used on the miniature model and on the website. To come up with different ideas for the logo a brainstorm session was held. The first part of the brainstorm session was about coming up with a name which will be used in the logo. Finding a name for the project was done by coming up with as much words as possible related to the project. A section of those words is shown below:

Liquid Natural Gas (LNG)	Transportation	Fuel
Liquid	Chain	Methane
Miniature	Pipelines	Ship
Model	Liquefaction	Students

After coming up with the words, three different designs were made. In those three designs different project names were used. The first design is shown in Figure 7 First try for the project logo. The methane molecule is playing the most important role in this design. The methane molecule is chosen, because methane is the main component of LNG. A 3D version of the molecule is used to make the logo more dynamic. The text: LNG Transport, was chosen in the beginning to describe the project in two terms.

The same text was used in the second design, which is shown in Figure 6 Second try for the project logo. For this design an image of a LNG ship was used to show the transportation of LNG, which is an important part of the project.

The last design is shown in Figure 5 Third try for the project logo. In this logo a different text was used to describe the project. The team came to the conclusion that LNG transport was not describing the whole project, so 'LNG chain' was used. The droplet shows the liquid phase of the LNG and the two arrows show the transition of the natural gas in the process. The yellow arrow is presenting the gaseous phase and the blue arrow the liquid phase. An industrial font is used to give the logo a more industrial look.

Figure 7 First try for the project logo

Figure 6 Second try for the project logo

Figure 5 Third try for the project logo

The team discussed the three designs and came to the conclusion to choose the third one. The first one was not picked, because the methane molecule was not showing the transformation the natural gas is going through. The second logo was not chosen, because the use of the ship made it look like the project is only about the shipping part. The third was chosen, because the team agreed that this logo includes all aspects of the project.

2.5 Website

The website about the project is made with the WordPress software. WordPress is currently behind 26% of the total web, which makes it the most popular online publishing platform. WordPress can be used to build a website without having any technical knowledge about building a website (Wordpress.com, 2017). None of the team members had real experience in building a website, so WordPress was chosen as software.

The website can be found at: https://lngtransportationmodel.wordpress.com/. The homepage is the first page, see Figure 8 First part of the homepage of the project website.

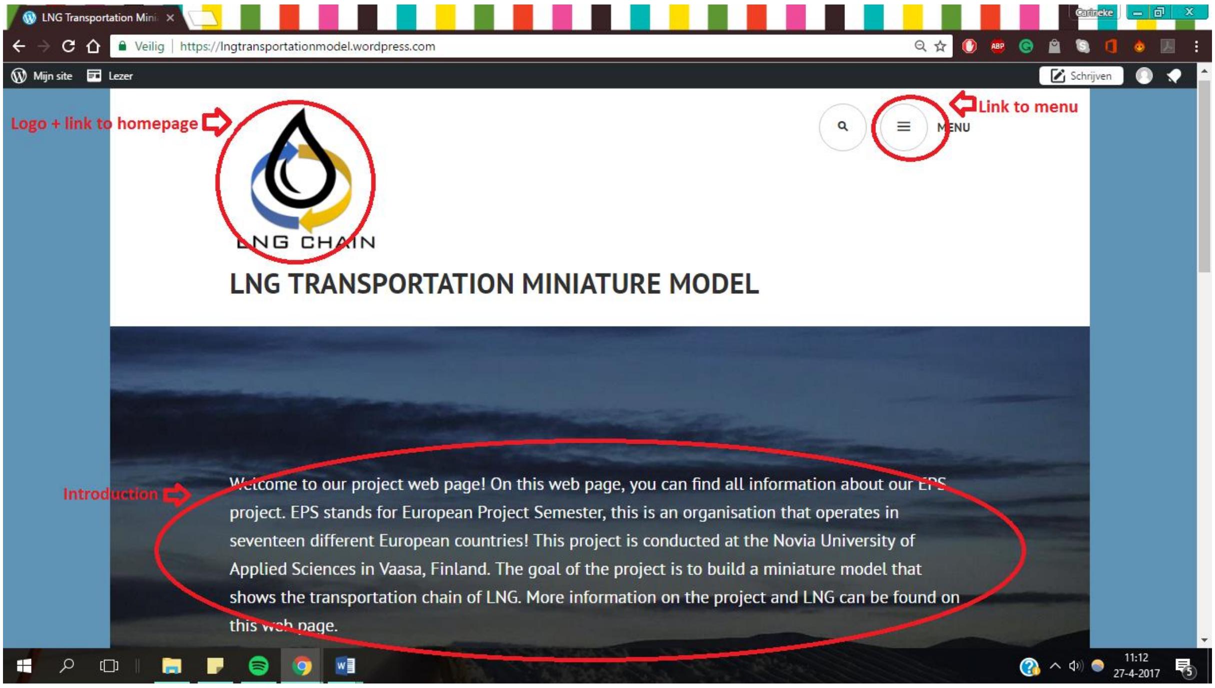


Figure 8 First part of the homepage of the project website

At the top of the page, the logo is shown, which is also a link to the homepage when the visitor is on another page. In the right corner there is a button to see the full menu of the website. Under the title a small introduction is given, explaining EPS and the goal of the project. Under the small introduction there are three links to other pages, shown in Figure 9 Second part of the homepage of the project webpage. Those pages are:

- Liquid Natural Gas: On this page information on LNG and the transportation chain can be found. A process flow diagram is added to support the theoretical information.
- Design Miniature Model: This page contains information on the way the miniature model is designed and built. Some pictures of the process and some sketches are added.
- Final Miniature Model: On this page, the final miniature model is presented by showing pictures and a 360^{o} movie. For teachers it is possible to download the Teacher manual from this page, to get the information about the model.

In the left corner the location of the project team shown, in the middle a small summary and in the right corner a menu.

Besides the three pages shown in Figure 9 Second part of the homepage of the project webpage there is also a page where the visitor can meet the project team. This page can be accessed through the menu in the header and in the footer. The page contains information about the team members, a group picture and a picture of each team member.

The website contains also a contact page. On this page it is possible for visitors to leave a comment or to ask questions. The menu can be used to access this page.

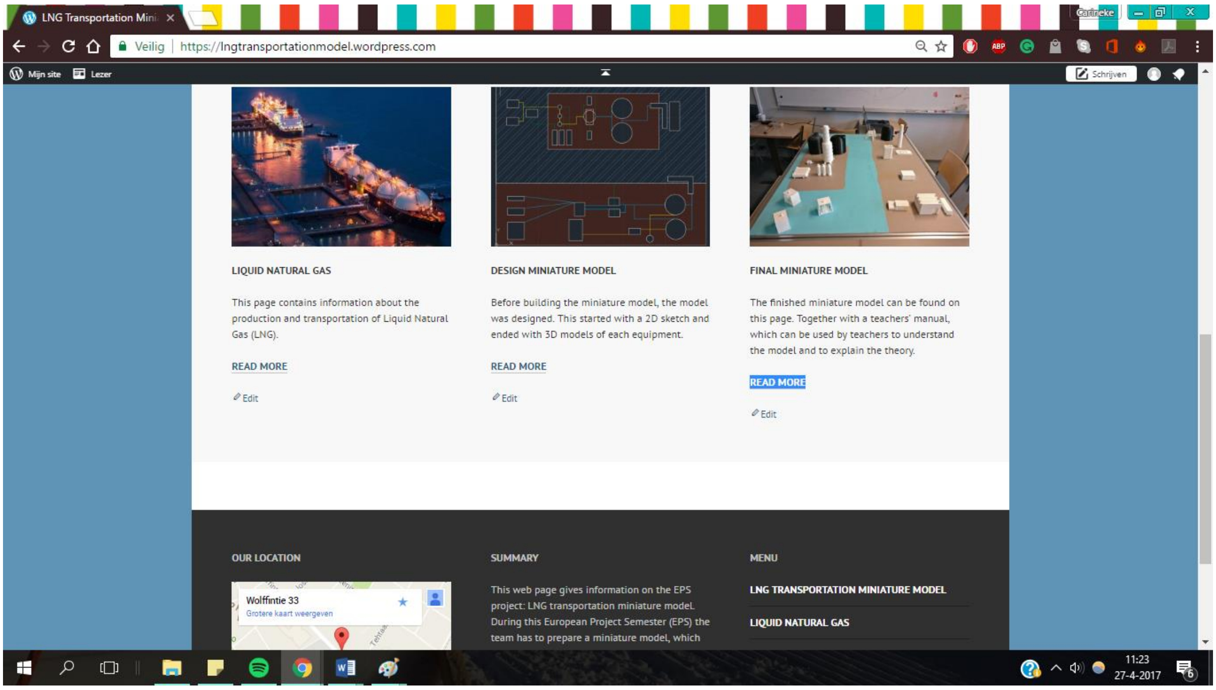


Figure 9 Second part of the homepage of the project webpage

3. Project Management Summary

The project work starts with the project management. Project management is a discipline to plan and execute a project in a team. Project management should increase the chance of successfully achieve the specific goals set by the client of the project. Project management includes for example: defining the beginning and the end, setting the scope of the project, setting deliverables, setting deadlines, defining the risks and making a planning. The project management done for this project was described in the midterm report, in this report a summary on the management will be given.

3.1 Scope of the project

The scope of the project is to provide Novia University of Applied Sciences with an interactive and educative miniature model of the LNG transportation chain. This model should provide teachers with a tool to educate students about the way LNG can be transported.

3.1.1 Stakeholders

The stakeholders are listed below:

- Teachers of Novia University of Applied Sciences
- Students of Novia University of Applied Sciences
- Project group
- Project coordinator: Andreas Gammelgård

The teachers will use the model to educate the students. To communicate with the teachers the project group will communicate with the project coordinator.

3.1.2 Deliverables

The deliverables of a project are defining the steps taken to reach the final goal. In this project the following deliverables have to be finished:

- Study report
- 2D sketch
- 3D sketch of each equipment
- Printed models of each equipment
- Miniature model
- EPS documents:
  - Midterm report
  - Midterm presentation
  - Final report
  - Final presentation
  - Project website
  - Movie about EPS

The first four deliverables are supporting the miniature model. Without finishing these deliverables it is not possible to make the miniature model. The EPS documents are mandatory for all EPS projects.

3.1.3 Work Breakdown Structure

From the deliverables set in section 3.1.2 a work breakdown structure (WBS) is made. A work breakdown structure (WBS) is used to convert a list of deliverables into a list of tasks. The main determined tasks are:

- Midterm report
- Midterm presentation
- Final report
- Final presentation
- EPS movie
- Project webpage
- Study production of NG
- Study liquefaction
- Study Shipping and regasification
- Study shape of equipment
- 2D sketch
- Investigating electrical work
- Modelling all equipment
- 3D printing all models

3.1.4 Technical requirements

For building the miniature model two main technical tools are used, one to design the models and one to program digital screens for the model. For the design Autodesk Inventor is used and for the programming Arduino. Both softwares should be available. During this project both of them are available and the team is able to work with them.

3.1.5 Limits and exclusions

In the first meeting with the project manager was decided to go for a physical model. By this decision other kind of models, like computer game, movie or virtual reality are excluded. The focus will only be on the physical model. An old model will be reused to construct the new physical model.

3.2 Time management

After setting the deliverables, it is important to manage the time planning. This is done by preparing a Gantt chart with MS Project.

3.2.1 Gantt chart

The WBS is used to prepare the Gantt chart. The Gantt chart is giving an overview of the planning and the milestones for the project. The Gantt chart will be used to make sure deadlines are reached and the result of the project is as required.

The Gantt chart is made with MS Project and is added in Appendix A.

The important deadlines are:

Midterm report	31-05-2017
Midterm presentation	03-04-2017
All models designed	23-03-2017
Miniature model is fully installed	17-04-2017
Final report + EPS movie + Project webpage	16-05-2017
Final presentation	16-05-2017

3.2.2 Thresholds

As can be seen in the Gantt chart, every task has a limited time. Inconveniences could happen, which could result in delay. To make sure the delays will not affect the end result, thresholds are used.

One of the important tasks in this project is modelling the equipment used in a 3D drawing computer program called Autodesk Inventor. Since there is no experienced team member, it is hard to estimate the time needed for the modelling. The time set is three days, but when the time needed for one model exceeds, it will be hard to print all the models on time. To make sure this will not happen, it is important to undertake action if after two days of working at the model there is no visible process. The action one can undertake can be using a different program, like Siemens NX, or another team member could try to make the model.

Another uncertainty in the tasks is the building of the models. This is done by 3D printing. It is known that this is possible, but real details are still unsure while making the Gantt chart. It is unknown how many printers are available and what the duration of printing one model is. When at the 26 of March not half of the models are printed, other possibilities for building the models should be used or it must be sure that the models are finished on time.

3.3 Risk management

Projects without risks do not exist, the chance that something goes wrong or mistakes are made is always there. It is not because of the risks that a project can fail, it is because the team neglects the risks and therefore when a risk occurs the impact will be much bigger. To make sure the risks are dealt with in an efficient way, the team must try to figure out what the risks are and how to deal with them beforehand.

The risks can be divided into 3 different groups:

1) Technical risks
    a. Lack of software
    b. Lack of software knowledge
    c. Lack of material
    d. Lack of mechanical knowledge
    e. Not enough time to print
2) Management risks
    a. Communication problems
    b. Bad planning
    c. Conflicts in team
    d. Different visions in the team
    e. Lack of focus/ambition
3) External events
    a. Too many/long trips
    b. Sickness
    c. Lack of money

Table 1 Risk management

Risk	Probability (1-10)	Impact (1-10)	Total	Mitigated	Prevented
Communication problems	7	7	49	x	
Lack of software knowledge	7	7	49	x	
Lack of mechanical knowledge	5	7	35	x	
Too many/long trips	6	5	30	x	
Bad planning	4	7	28		x
Not enough time to print	3	8	24		x
conflicts in the team	3	6	18		x
Lack of focus/ambition	3	5	15		x
Sickness	5	2	10		x
Lack of correct Software	1	8	8		x
Not enough material (paint, glue, etc.)	1	7	7	x	
Different visions in the team	2	3	6		x
Lack of money	2	2	4		x

Multiplying the probability of a risk with the impact the risk causes gives a total percentage of the intensity of the risk as seen in Table 1 Risk management. A higher percentage means that the risk is more likely to occur and the impact will be bigger. It is thus important to mitigate these risks. Mitigating the risk is not always possible, so controlling the risk will become even more important. Handling the risk badly can leave the project in a dangerous situation. A discussion how the risks were handled can be found at chapter 7.2.

4. Study report

Before the designing is started, research is done on the LNG transportation chain. The results of the research are discussed in this section.

In Finland 8% of the energy consumption is covered by natural gas, which is a small amount. Most of the energy is gained from wood. Nevertheless, 30.000 homes in Helsinki are using natural gas for cooking or property heating. There is a gas transmission network in the southern area of Finland, in the triangle within Tampere, Imatra and Helsinki. This network includes: pipelines, metering stations at the gas delivery points, valve stations and compressor stations. The natural gas consumed in Finland is imported from Russia, because Finland does not have its own natural gas source.

By liquefaction, the natural gas is turned into liquid natural gas (LNG). LNG is more accessible than natural gas, because the volume of liquid natural gas is significant smaller (600 times smaller) than natural gas is. LNG can be shipped from different countries overseas to Finland, which makes it unnecessary to build and invest in more pipelines. In addition, natural gas is the cleanest fossil energy source because during combustion it does not create any sulphur or heavy metals emissions. Thus, investing in the LNG chain would be more profitable (Gasum, 2017).

The different steps in the LNG chain needs to be determined before a sketch can be made of the transportation system. The LNG chain is shown in Figure 10 LNG value chain (Wärstilä, 2017).

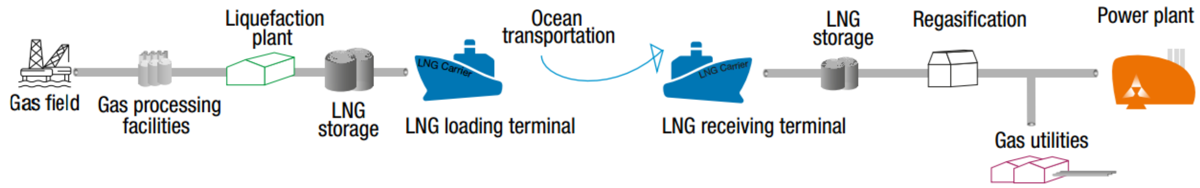


Figure 10 LNG value chain

4.1 Production of NG

The production of liquid natural gas finds place in Snøhvit, Norway. This is the most northern situated offshore gas production plant. The location can be seen in Figure 11 Location of Snøhvit on the map of Norway. The gas is extracted from the subsea with a capacity of 17.000 m³ natural gas per day. This gas is transported to Melkoya, a small island on the shore of Norway next to Hammerfest. During extraction of the natural gas a significant amount of carbon dioxide will be extracted together with the natural gas. Instead of releasing this useless carbon dioxide in the atmosphere it will be

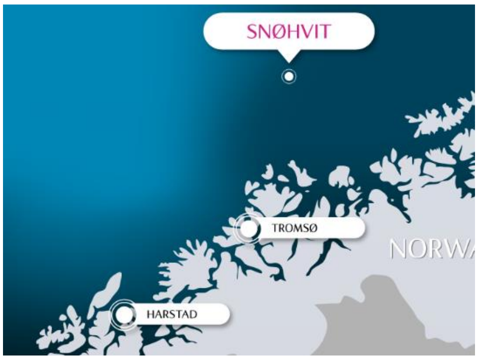


Figure 11 Location of Snøhvit on the map of Norway

extracted and pumped back to Snøhvit. Here is the carbon dioxide injected back into the ground below the gas-bearing formation. This technique reduces the carbon dioxide emission by 700.000 tons per year.

Figure 12 Model of the production well in Snøhvit

The Snøhvit gasfield consists of 3 separate fields: Snøhvit, Albatross and Askeladd. The gas is extracted using 8 production wells operated by Statoil on behalf of 6 gas companies (Statoil (33%), Petoro (30%), TotalFinaElf (18.4%), Gaz de France (12%), Amerada Hess (3.26%) and RWE Dea (2.81%). By building the well, the gas rises to the surface due to its natural tendency to fill areas with the lowest pressure. Next, the gas is transported by pipelines to Melkoya. In addition, there is one umbical, two chemical pipelines and a CO2 pipeline. (Offshore Technology, 2017)

Figure 13 Example of natural gas purification equipment

During the construction of this plant the focus was particularly on the ecological impact. There are no mobile drilling barges or platforms because everything happens on the seabed. The parts are specifically designed to form no obstacle for fishing. A model of the production well is shown in Figure 12 Model of the production well in Snøhvit.

In total, the Snøhvit gas field extracts around 4% of the total world production while being the most environmental friendly liquefaction plant in the world (World-Oil, 2016)

4.2 Purification

After the natural gas is transported from the ocean to land, the natural gas needs to be purified. The natural gas contains some non-hydrocarbons, like hydrogen sulphide, nitrogen, carbon dioxide and water. These compounds need to be removed before the liquefaction, because otherwise residue will build-up. Firstly, a solvent is used to remove carbon dioxide, hydrogen sulphide and water. The heavier liquids are removed to be used for separated processing. The last step is to remove the last water in the gas. The pure natural gas is transported to the liquefaction plant (ExxonMobil, 2016).

In industry the purification is done by different equipment, but the most common equipment used is shown in Figure 13 Example of natural gas purification equipment.

Figure 14 Cryogenic heat exchanger tower used for liquefaction of natural gas

4.3 Liquefaction

There are two main technologies that Wärtsilä is using to liquefy the natural gas: the mixed refrigerant cycle and the reversed Brayton process. The principle of liquefaction is cooling the gas to at least -162^{o}C, which is below the boiling point of methane. When the temperature drops under the boiling point, the gas is transformed to liquid phase. In the liquid phase the volume is decreased 600 times.

The mixed refrigerant cycle is based on a mixture of refrigerants and a screw compressor is used to compress the refrigerant to the right pressure and temperature for the cooling process. This method is used for a plant with a capacity below 50 thousand barrels per day (TPD) (Wärtsilä, 2017).

The Reverse Brayton cycle is using nitrogen as the refrigeration medium. The nitrogen can be produced on site. To obtain the right temperature the nitrogen is compressed and expanded. This method is preferred for a small scale liquefaction (< 50 TPD) (Wärstilä, 2017).

To produce liquid natural gas on a big scale the Mixed Fluid Cascade (MFC) from Linde is a solution. This process is comprised of three separated mixed refrigerant cycles. Those refrigerants are having a different composition, to ensure minimum compressor shaft power requirement. The cooling for liquefaction and pre-cooling is done with coil-wound heat exchangers. The MFC method is used in Hammerfest, Norway and is having a capacity of 4.3 million tons per annum (The Linde Group, 2017).

The most used heat exchanger for the liquefaction is the cryogenic heat exchanger tower. This heat exchanger is shown in Figure 14 Cryogenic heat exchanger tower used for liquefaction of natural gas. It is also possible to use different kind of refrigerants as explained in the Mixed Fluid Cascade definition. The cryogenic heat exchanger is using two different cooling circuits with two different refrigerants. Figure 15 Cross section of a cryogenic heat exchanger shows that there are two inputs with refrigerant, one at the top and one on the side. The refrigerant which is entering the heat exchanger from the top is distributed through the atmosphere in the heat exchanger. This refrigerant is flowing over the pipelines filled with natural gas. The second refrigerant is entering the heat exchanger at the same level as the feed and is in flowing in a pipeline around the natural gas pipeline. The temperature of the second refrigerant should be lower than the first one, because the second one is cooling the natural gas down at the end of the cooling down process (Coyle & Patel, 2016).

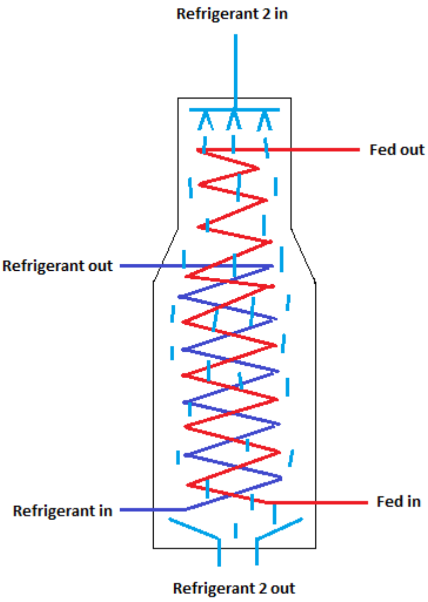


Figure 15 Cross section of a cryogenic heat exchanger

After liquefaction the liquid natural gas will be stored in storage tanks. Storing happens until the liquid natural gas can be loaded on a ship.

4.4 Storing

The gas is stored in the tanks, which keeps the gas at -162 °C. The tanks at the liquefaction plant and the terminal are the same. An LNG import terminal designer faces with two important storage-related decisions: how many tanks to build and the type of storage tank required. Given that the LNG import terminal is often the only or main source of gas in a region, it is essential for its proponents to ensure the facilities are able to manage with unexpected surprises,


Figure 16 Example of LNG storage tanks

like a delay in a freight delivery. The selection of a reservoir design and the associated foundation design will be influenced by several factors, in particular the geology, topography and soil conditions of the site, in particular with regard to vaporise dispersion and exclusion zone requirements and of course aesthetic considerations. Examples of storage tanks are shown in Figure 16 Example of LNG storage tanks (Falco, 2015).

4.5 Shipping

The LNG transportation is easiest by ship. A LNG ship contains three to four spherical storage tanks on board. Those tanks need to be prepared before the loading of LNG can take place. Firstly, the tanks are filled with an inert gas, which is reducing the risk of explosion. Secondly, the tanks are cooled-down. The cooling-down process is done by spraying LNG into the tanks, which by vaporising cools down the environment inside the tank. After the tanks are cooled, the LNG is pumped from the on-site storage tanks into the vessel tanks.

Basically, two vessel technologies are applied:

The Floating Storage Unit (FSU). This ship is used exclusively to transport the LNG, from the reservoirs at sea to the terminal. This kind of technology is shown in Figure 17 Example of the floating storage unit.

Figure 17 Example of the floating storage unit

The Floating Storage and Regasification Unit (FSRU). In this unit the regasification plant is assembled. So, the regasified natural gas can be fed directly to the grid. In this report this technique will not be explained in further detail. An example of a tanker with this technique is shown in Figure 18 The floating storage and regasification tank (Falco, 2015).

Figure 18 The floating storage and regasification tank

4.6 Boil-off-gas

When heat increases in the equipment or facilities containing LNG, partial evaporation of the LNG is happening. The gas appearing is called the boil-off gas (BOG). If the BOG is not evacuated, the pressure increases in the tanks. To prevent this, compressors are used which maintain a stable pressure in the storage tanks. The BOG is evacuated to units of reincorporation where it is mixed with the emitted LNG.

Terminal installations require good insulators, especially liquid reservoirs and ducts, because LNG is a cryogenic liquid. A boiling of 0.05% per day of the reservoir volume is observed. Terminals are equipped with a system which is capturing the BOG or a system to compress the gas and export it. The boil-off rates are higher when unloading the LNG tanker, because of the energy transferred during the pumping process. Part of the excess vapours are returned to the LNG carrier to maintain pressures in the vessels. If the terminal has its own gas-fired power generator, the residual gas can be used to generate the power needed for the plant. A remote flare stock is available to dispose the BOG when there is an equipment failure or when the BOG rate is exceeding the capacity of the recovery system (Tusiani & Shearer, 2007).

4.7 Regasification

In the regasification process the LNG is transferred into gas again. This process can be done by different heat exchangers or vaporisers. The most applied regasification technologies are: open rack vaporiser, submerged combustion vaporisers and cryogenic heat exchangers.

The first is an open rack vaporiser (ORV): Liquid LNG is located inside panels and sea water is running down in the opposite direction on the outside of the hollow panels. By this action, the LNG in the panels is heated by the flow of sea water. To prevent fouling of vaporisers by marine growth, seawater and vaporisation systems must be treated with chemicals. These have an impact on the ocean environment, as the treated seawater is discharged into the ocean. The discharge of cold water into the sea also poses environmental problems, the fluctuation of water temperature has a negative impact on marine flora and fauna. To reduce this impact, sea water is heated with an intermediate fluid before being discharged into the ocean (Tusiani & Shearer, 2007).

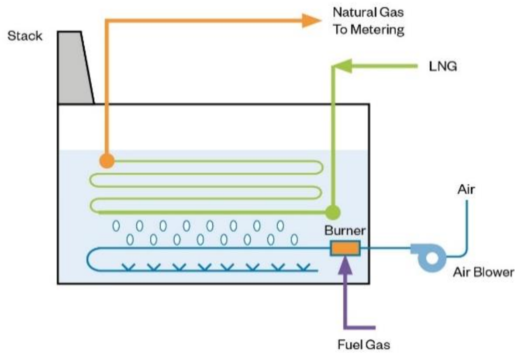


Figure 19 Overview on streams in an open rack vaporiser

Figure 19 Overview on streams in an open rack vaporiser, gives an overview on the streams in an open rack vaporiser. In Figure 20 Example of an open rack vaporiser, is an example of the equipment shown.

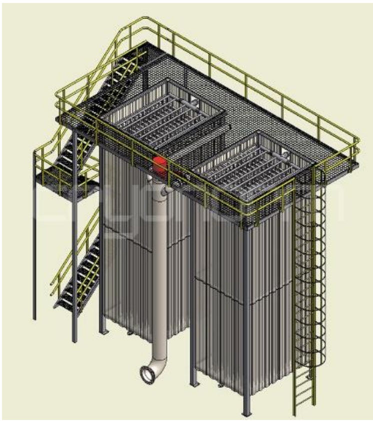


Figure 20 Example of an open rack vaporiser

The second is a submerged combustion vaporisers (SCV): This equipment has several devices: the burner, combustion-air fan and fuel-supply control device, a bundle of heat-transfer tubes and a tank. It submerges the burner in the liquid gas, which burns a combustible gas which heats the gas in order to vaporise it. It then becomes gaseous natural gas againFigure 19 Overview on streams in an open rack vaporiser (Falco, 2015).

Gas vaporisers are often cheaper and smaller than ORVs, as a large area is needed to heat LNG at a lower ambient temperature than sea water.

The last heat exchanger that can be used is the same kind as used for the liquefaction, the cryogenic heat exchanger

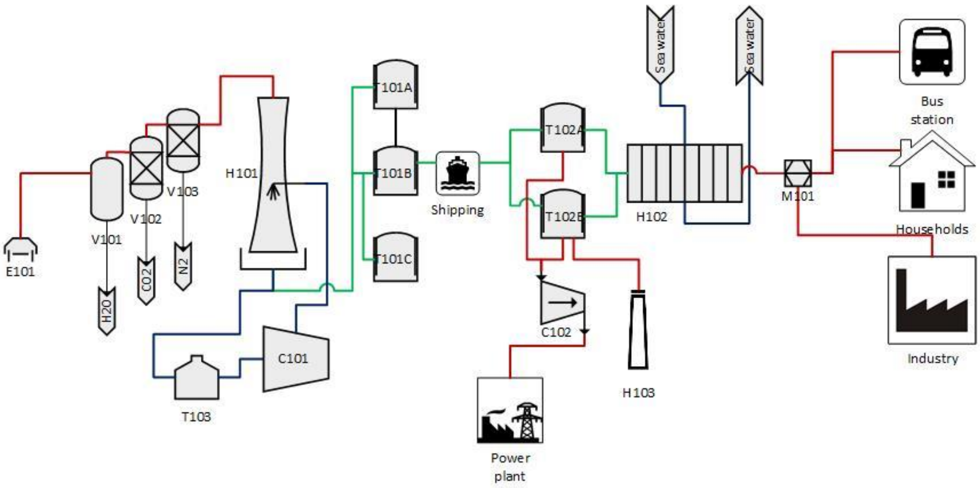
4.8 Users

Before leaving the terminal, the regasified LNG passes through a pressure-regulating and metering station to measure the gas. The gas may be odorized to aid in the detection of any leaks in the gas transportation system or customer appliances.

After the metering station the gas is ready to be sent to the different users. The users could be households, public transportation buses or the industry. For transportation to the users is it possible to use the piping system for natural gas (Falco, 2015).

4.9 Process flow diagram

The different theory parts are used to draw a process flow diagram (PFD). This PFD gives an overview of the total process used to transport LNG. The PFD is shown in Figure 21 Process Flow Diagram of the transportation of natural gas and liquid natural gas. Red means gas phase, blue means refrigerant and green means liquid phase.



Number	Name	LNG or NG		Number	Name	LNG or NG
E101	Production well	NG		H102	Open rack vaporiser	LNG/NG
V101	Purification tank 1 (H2O)	NG		M101	Metering station	NG
V102	Purification tank 2 (CO2)	NG		T103	Storage tank Refrigerant	-
V103	Purification tank 3 (N2)	NG		C101	Compressor Refrigerant	-
H101	Cooling tower	NG/LNG		H103	Chimney	NG
T101	Storage tank LNG	LNG		C102	Compressor Boil-off-gas	NG
T102	Storage tank LNG	LNG				

Figure 21 Process Flow Diagram of the transportation of natural gas and liquid natural gas. Red means gas phase, blue means refrigerant and green means liquid phase.

5. Designing the model

After the research stage was finished the designing of the model started. It started with two brainstorm sessions, where different sketches were prepared on the whiteboard in the EPS room. The final sketch from the brainstorm session is shown in Figure 22 Final sketch after the brainstorm sessions on the whiteboard.

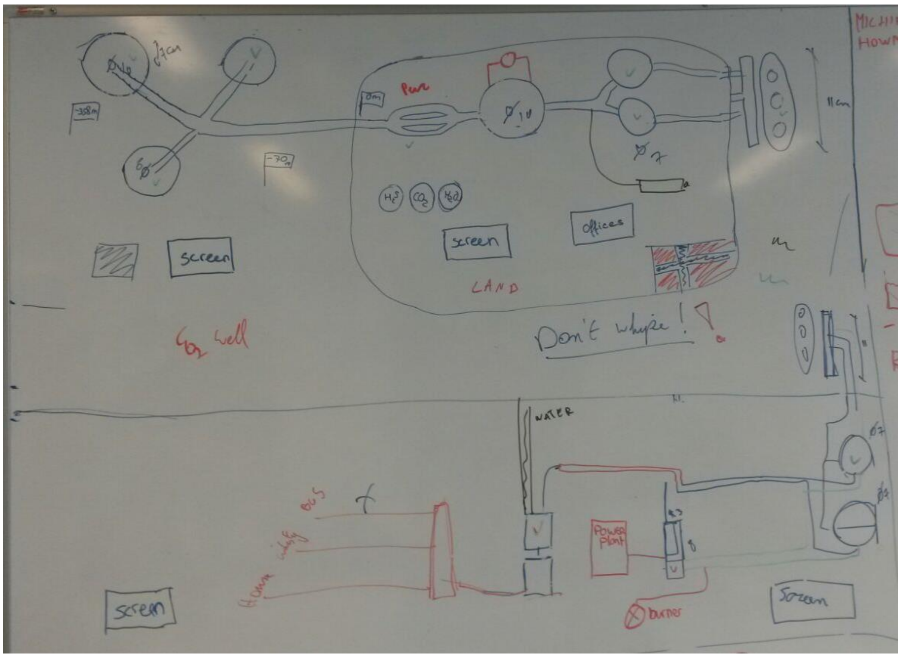


Figure 22 Final sketch after the brainstorm sessions on the whiteboard

5.1 2D Sketch

As soon as the sketch on the whiteboard was finished a professional one was made using Autodesk Autocad, shown in Figure 23: 2D sketch. Different colours were used to map out the pipelines. The yellow represent the gas state, blue for the liquid state and green pipelines for the by-products. Using this sketch the dimensions of each model are known and the models could be designed. This sketch and dimensions are also used to paint the wooden board of the model.

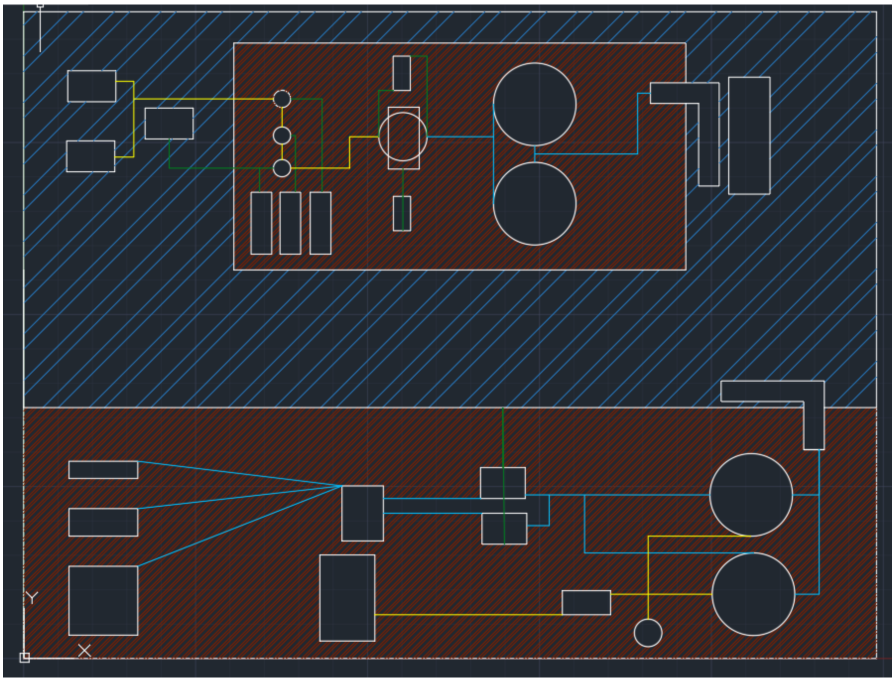


Figure 23: 2D sketch

5.2 3D Models

In this section a brief overview of the different models is given. Hereby it is explained why some simplifications are made and why the team chose for these specific models. For every model there will be a picture of the existing situation, the 3D sketch and the finalised printed model.

All of the models were printed using the Wanhao duplicator 5S, This printer uses 2.85mm PLA filament to print all the models. The models were first designed using Autodesk Inventor and Siemens NX. After the designing a .stl file was created (3D print preview). Using the Wanhao duplicator software the model can be sliced into the different layers and support structures are built around it.

Figure 24: Wanhao duplicator 5s

5.2.1 Production well and Carbon dioxide reinjection well

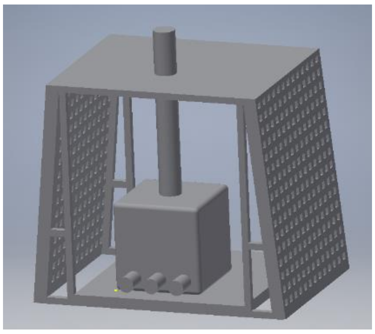


Figure 25: Production well model *Figure 26: Production well*

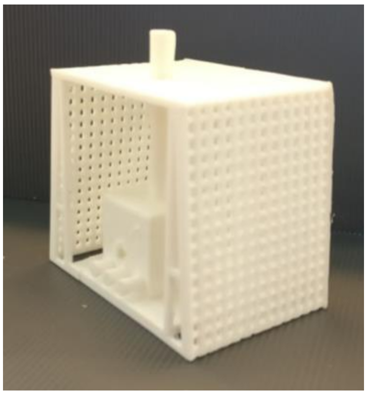


Figure 27: Production well printed

For the modelling of the production well there was an important focus on the diagonal shaped frame. These are constructed in this specific way so fishing nets cannot get stuck or tangled behind the frame. The interior which consists of different pipes is simplified so that the 3D printer has no difficulties. In order to keep it realistic, three pipelines are constructed at the bottom of the box. These include: one umbical pipeline and two chemical pipelines. For the gas production well, the big pipeline pointing upwards will extract the gas and transport it to the liquefaction plant. The carbon dioxide well has the same connections but the main pipeline now transports carbon dioxide. This carbon dioxide is reinjected below the gas bearing formation.

5.2.2 Purification step

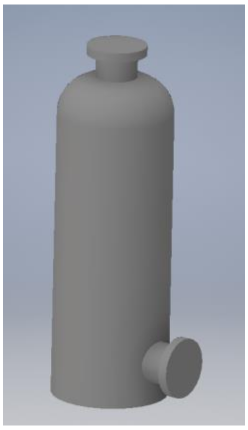


Figure 28: Purification tanks *Figure 29: Purification tank model* *Figure 30: Purification tank printed*

During the production step the gas gets purified. Two flanges are needed for the gas and one for the non-hydrocarbons like nitrogen. Using this flange these compounds can be removed and stored in a bullet tank. When the bullet tank is full these compounds can be sold separately. The carbon dioxide that is produced during the process will travel back to the carbon dioxide injection well.

5.2.3 Bullet tank

Figure 31: LNG bullet tank

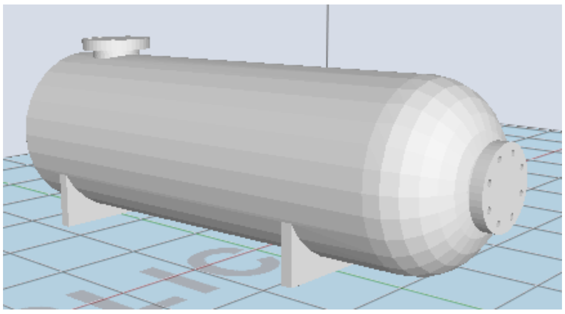


Figure 32: LNG bullet tank model

Figure 33: LNG bullet tank printed

The bullet tank is designed pretty straight forward, with one flange at the top of the tank where the pipeline delivers the different compounds and a second flange at the side of the bullet tank where the compounds can be removed from.

5.2.4 Heat exchanger

Figure 34: Heat exchanger

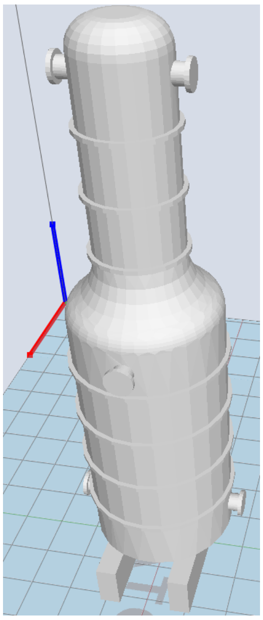


Figure 35: Heat exchanger model

Figure 36: Heat exchanger printed

The heat exchanger used in the miniature, uses two different cycles of cooling. One runs all the way from the top and the others starts where the heat exchanger narrows.

5.2.5 Flat bottom Storage tank

Figure 37: flat bottom storage tank

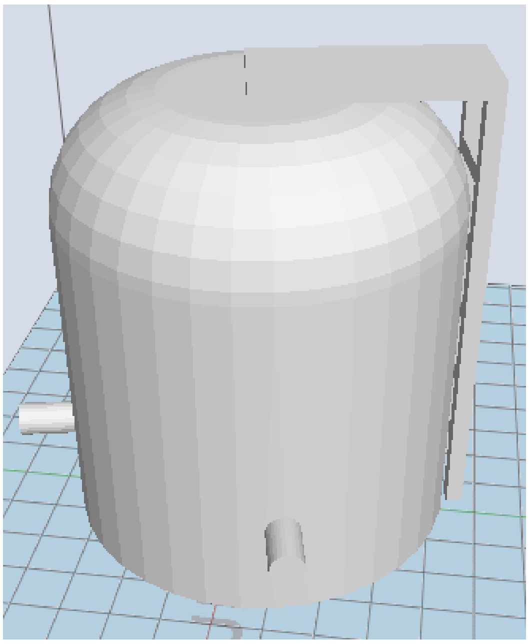


Figure 38: flat bottom storage tank model

Figure 39: flat bottom storage tank printed

The storage tank has two flanges, one directly connected to the heat exchanger where the natural gas is liquefied. The other is connected to the shipping terminal where LNG tankers can fill their tanks and ship the LNG.

5.2.6 Shipping Terminal

Figure 40: LNG loading arm

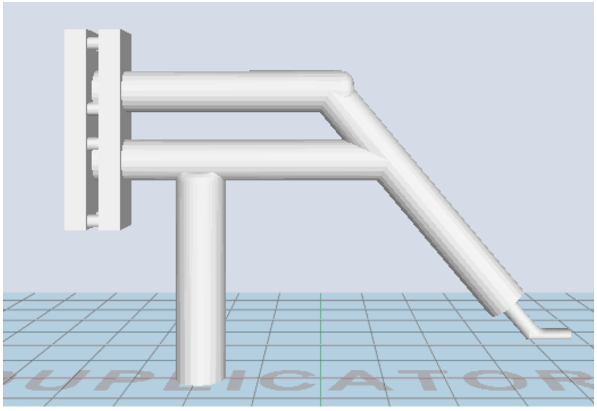


Figure 41: LNG loading arm model

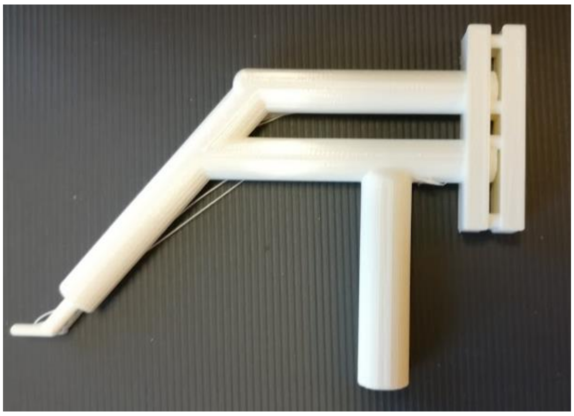


Figure 42: LNG loading arm printed

The modelled LNG arm has the same shape but less complicated in order to print it. Instead of using a truss structure a full cylinder is used. At the end of the LNG arm a counter weight makes sure everything is in balance.

5.2.7 LNG tanker

Figure 43: LNG tanker

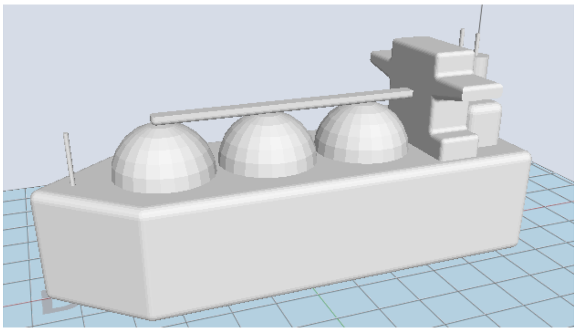


Figure 44: LNG tanker model

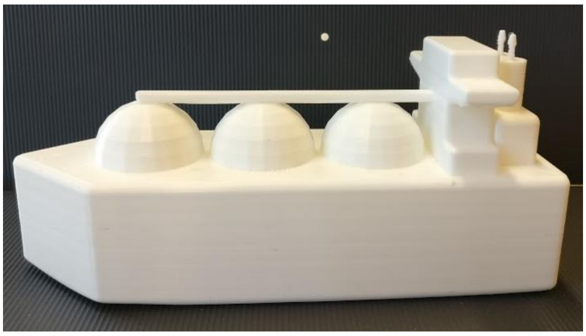
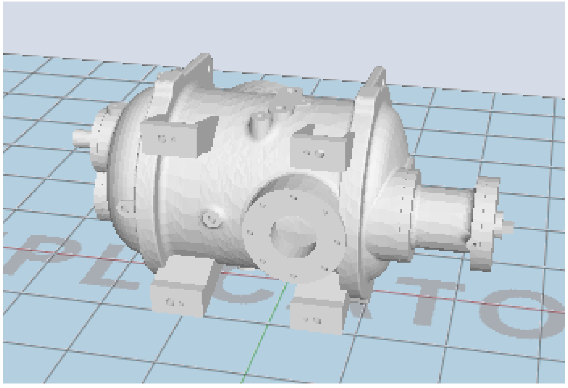


Figure 45: LNG tanker printed

The model of the LNG tanker displays the typical spherical shaped storage tanks. When completely filled, the tanker ships it to the regassification plant where it can be unloaded using the same LNG arms. During the shipment some LNG will evaporate, the tanker can use these fumes as fuel.

5.2.8 Compressors

Figure 46: LNG Compressor



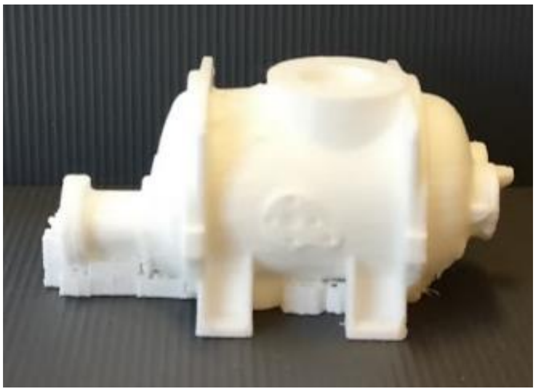


Figure 47: LNG Compressor model *Figure 48: LNG Compressor printed*

In order to make a printable model the different pipelines are removed. This gives a clean model that gives an impression of a compressor. The model will be used both for the boil-of-gas and the refrigerant of the heat exchanger.

5.2.9 Chimney

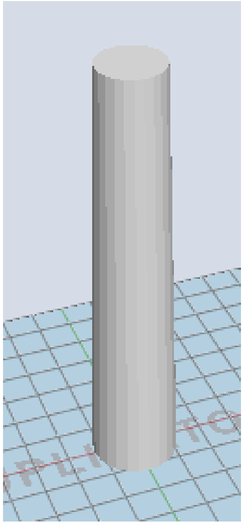


Figure 49: Chimney printed *Figure 50: Chimney model* *Figure 51: Chimney*

The chimney is used to burn of excessive BOG in case the compressor cannot handle everything or there is a technical problem.

5.2.10 Open rack vaporiser

Figure 52: Open Rack Vaporiser

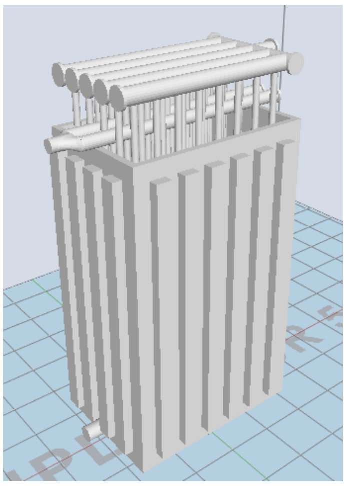


Figure 53: Open Rack Vaporiser model Figure 54: Open Rack Vaporiser printed

The open rack vaporiser uses seawater that is sprayed over the tubes to warm up the LNG in order to put it in its gaseous state. The LNG goes in at the bottom flange where it is transported upwards. The seawater is poured in the opposite direction so it is as efficient as possible. On the outside of the ORV there are cooling ribs to distribute the heat even better.

5.2.11 Power plant

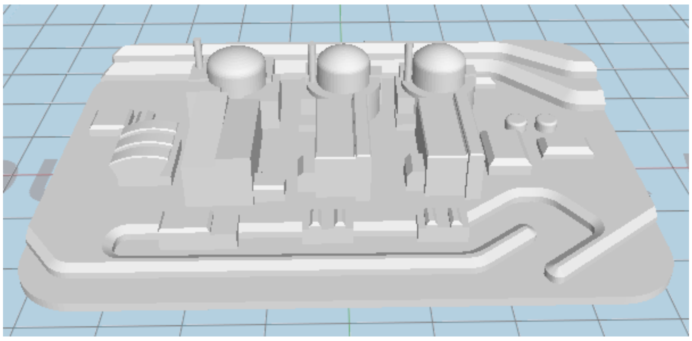


Figure 55: Power plant model

Figure 56: Power plant printed

For the power plant a predefined model is used. This because it is not a part of the LNG chain of value but it is an important user of the BOG. The power plant can use this energy which is more efficient than to burn it using the chimney.

5.2.12 Metering Station

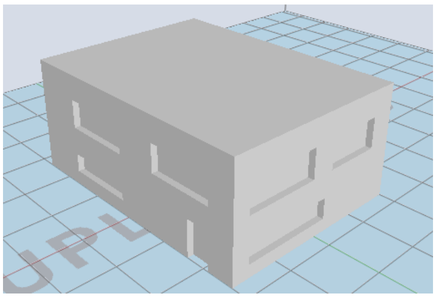


Figure 57: metering station model

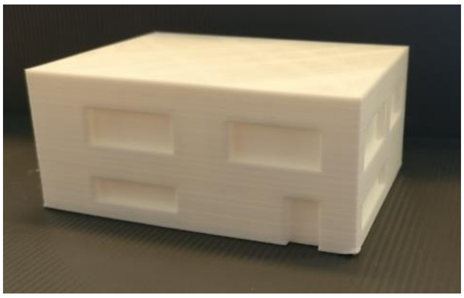


Figure 58: metering station printed

After the open rack vaporisers the natural gas is ready to use for all the clients. Using a metering station the gas is distributed to the different end-users. The station was modelled after a standard office building.

5.2.13 Private houses

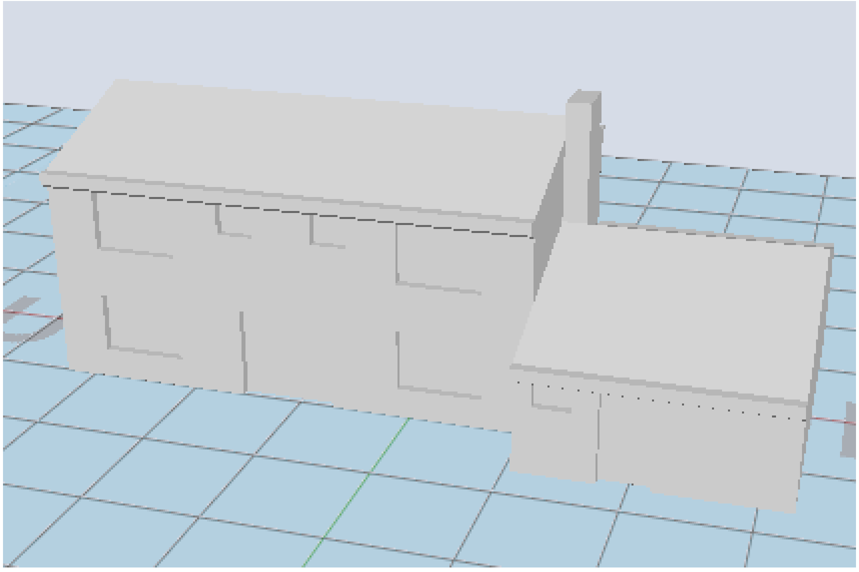


Figure 59: Private house model

Private houses can use the natural gas for cooking and heating. This model was designed without an example.

5.2.14 Public Transportation – Bus

Figure 60: Public bus

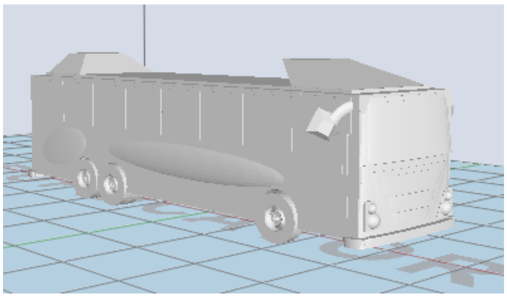


Figure 61: Public bus model

Figure 62: Public bus printed

During printing the mirrors appeared too small to print without breaking. Other details worked out fine. In the future busses like these will be common used because those are more environmental friendly as normal busses.

5.2.15 Industry

One of the main end-users is industry, this can contain every kind of industry buildings that needs energy to produce its products.

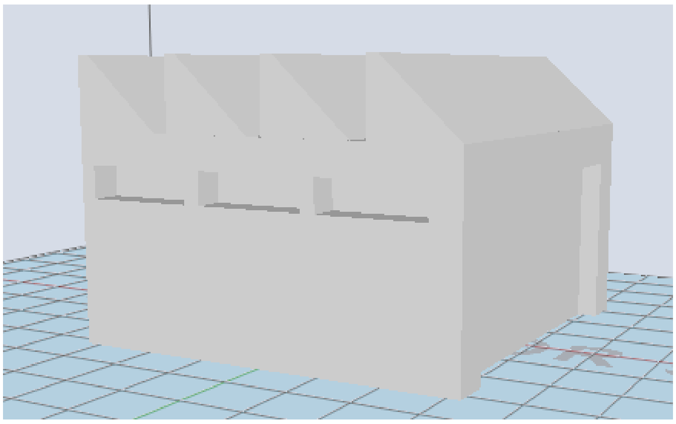


Figure 63: Industry building model

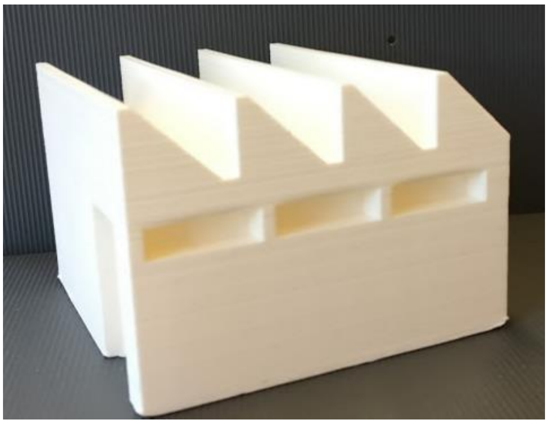


Figure 64: Industry building printed

5.3 Resizing

After the midterm presentation the team decided to take a look at the different models that were printed and critically analyse if the dimensions were correct. Because the real size of the equipment differs so significantly, no scales were applied when designing the models. However, after putting all the models together on the board the team decided to reprint some models smaller/bigger. These include:

- Decreasing the size of the heat exchanger
- Decreasing the size of the factory
- Increasing the size of the Purification towers
- Lowering the hull of the LNG tanker

On top of the resizing the team also decided to print all the storage tanks in white instead of black to be more consistent. In order to make sure the board is not too empty a second open rack vaporiser is printed. To top things of, a remodelled powerplant was made and printed. The reason for this is that the original powerplant had too little detail and the way it was modelled was totally different as the other models. The new powerplant blends in with the other models as shown in Figure 65: New powerplant.

Figure 65: New powerplant

5.4 Electrical work

Figure 66 The electrical system of the old model

The electrical circuit of the old model is recycled, which is shown in Figure 66 The electrical system of the old model. This circuit is used to power LEDs with push buttons.

A part of the circuit is recycled to use it on the new model. On top of that LCD screens are added to the miniature model to display messages and explain the process.

The Arduino is used to give the possibility of combining the performances of programming with these of electronics and more precisely to program several LCD screen.

5.4.1 Initial situation

An existing electrical system lights LEDs on the plane of the models, the location of the LED will be modified to adapt it to the new miniature model. Pictures of the electrical work form the old model are shown in Figure 67 to Figure 68.

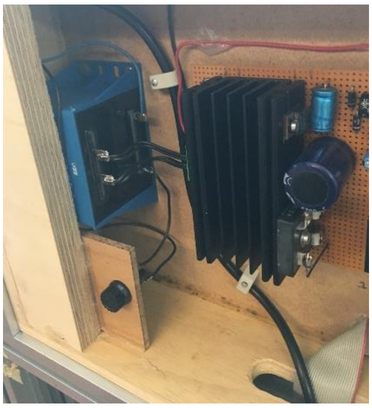


Figure 68 The power supply of the old model

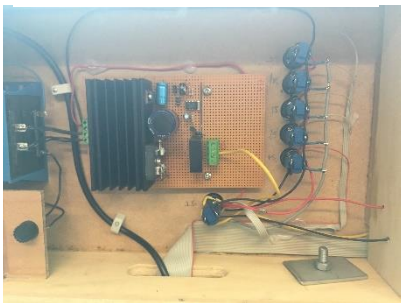


Figure 69 The motherboard of the old model

Figure 67 Total overview of the electrical system of the old model

5.4.2 General and Specific Objectives of the Project

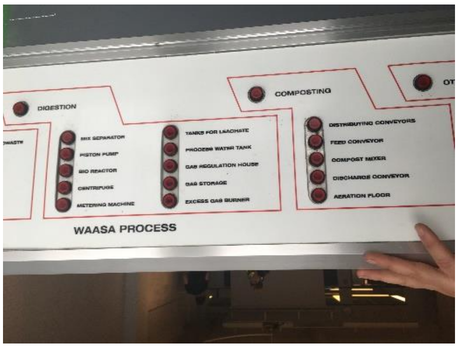


Figure 70 The buttons of the old model

To recycle the model, the buttons of the old model are used, shown in Figure 70 The buttons of the old model. Given the number of buttons that are used to explain the LNG process, five important steps in the LNG process are chosen and at each stage several elements are chosen. Nineteen switches are used on the project. Each button must light an LED on the model and display a message on one of the LCD screens shown on the models. The miniature model will use three LCD screens, every model will have a LED that lights up when the corresponding button is pressed. To make clear which LED correspondents to which button, a sticker with text is used, an overview of this is shown in Table 2 Overview of use of the buttons.

Table 2 Overview of use of the buttons.

NATURAL GAS PRODUCTION	LIQUEFACTION	SHIPPING	REGASIFICATION	USERS
Production well	Purification process	Liquefaction terminal	Storage tank	Industry
CO2 well	Heat exchangers	LNG tanker	Chimney	LNG buses
	Storage tanks	Regassification terminal	Boil-off compressor	Houses
	Bullet tanks		Open rack-vaporizer	Powerplant
	Refrigerant compressor		Measuring station	

5.4.3 The Problem of the Electrical Project

The previous model had a number of buttons associated with LEDs. During this project LCD screen are added next to the LEDs. Although the basic buttons can be recycled, because of the implementation of the LCD screen, the electrical wiring needs to be reworked. First of all, to reuse the existing LEDs, the team had to think about how to remove these effectively without losing too much time or breaking components. On top of that the question arose, what elements should be kept (feed and metal plate for maintenance of the buttons).

The steps taken to come to the decisions are shown in a diagram in Figure 71 Diagram of the steps taken to come to the decisions.

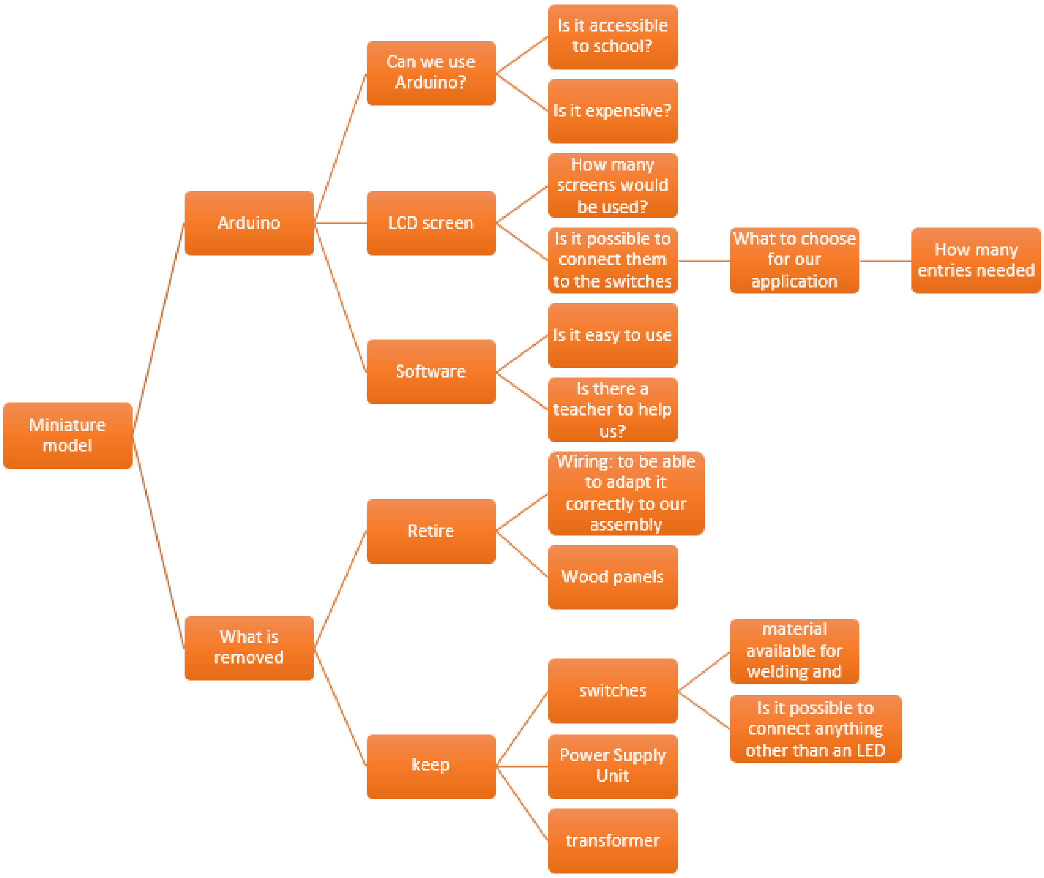


Figure 71 Diagram of the steps taken to come to the decisions

5.4.4 Understand how a components works

Unfortunately the recycled buttons do not have the full technical data sheets on the internet. The team struggled with this, because documentation could not be found to fully understand how the buttons worked. To be able to reuse the buttons it is important that the team fully understood the way they work. An overview on the information about the buttons is given in Table 3 Overview of the information about the buttons. The stages to study and understand the functioning of the buttons are shown in Figure 72: Steps that were taken to get information needed from the buttons.

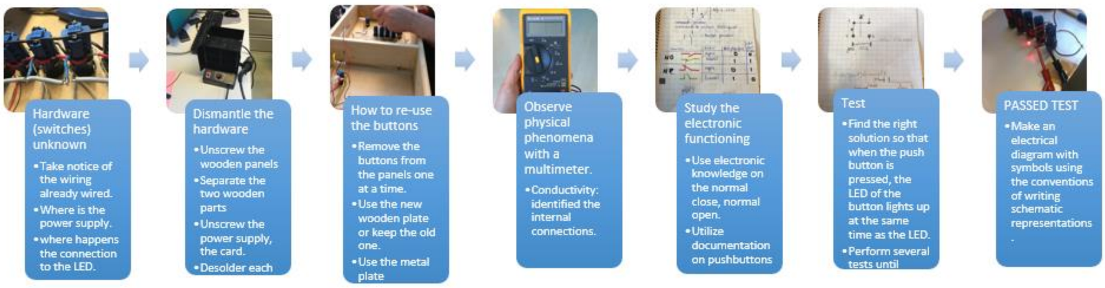


Figure 72: Steps that were taken to get information needed from the buttons

Table 3 Overview of the information about the buttons

Push Button Switch type RAFI model 1.15108.352 with a rated voltage of 250 VAC and rated current of 4 A, 2 NO + 2 NC, latching

Characteristics

Weight	0.020 Kgs
Code	20946
Type	Button type "RAFI", retentive
Colour led	red
Voltage contacts	250 VAC
Rated contacts current	4 A
Contact system	2 Normal Open (NO) + 2 Normal Closed (NC)
Degree of protection	IP40
Backlight	LED 42 VDC, 1.2 W
Installation of the conductor	Soldering
Mounting	panel
Housing material	high quality non-flammable plastic
Size of mounting hole	nut threaded M16
Height above the hull	7.5 mm
Dimensions	17.9 x 17.9 x 57.7

5.4.5 The necessary equipment

The system Arduino is composed of two main things: the equipment and the software. These Arduino boards were ordered with the help of Hans Linden. The software is shown in Table 4 Information about the software and the equipment is shown in Table 5 Information about the equipment.

Table 4 Information about the software

SOFTWARE	ARDUINO
General	Arduino is a free hardware circuit board with a microcontroller that can be programmed to analyse and produce electrical signals to perform a wide range of tasks, such as home automation (control of domestic appliances, lighting, heating, etc.). The software allows you to program the Arduino card. It offers a multitude of features.
Picture	

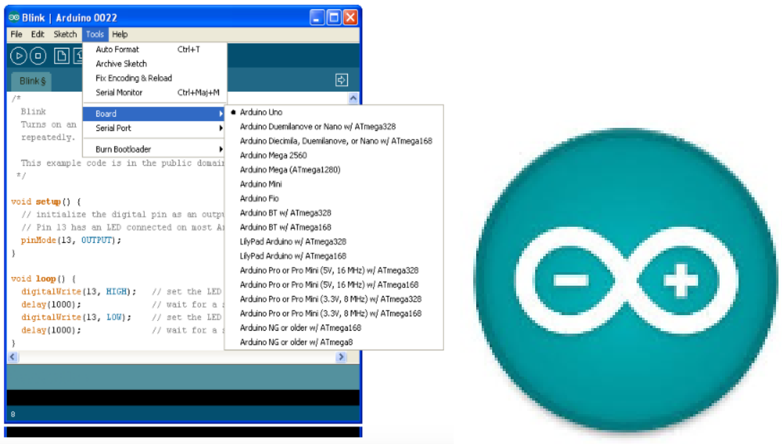


Table 5 Information about the equipment

EQUIPEMENT	**BOARD**	**LCD SCREEN 4004A**
General	This is a development board based around the ATmega 1280 manufactured by Atmel.	This is a standard controller for controlling a liquid crystal display device. Character LCM (Compatible with HD44780)

<table>
<tr><td>Picture</td><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td rowspan="2">components</td><td rowspan="2">Microcontroller</td><td colspan="2">Memory

The ATmega1280 has 128 KB of flash memory for storing code (of which 4 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).</td><td colspan="3">Terminals

An LCD4004B module has 18 terminals (the last two of which are optional if the screen does not have backlighting)</td></tr>
<tr><td colspan="2">The processor

The Arduino Mega is a microcontroller board based on the ATmega1280 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.</td><td colspan="3">Control

In 8-bit mode: In this mode, the byte containing the data is sent to the display (or read by the display) directly on pins D0 to D7.

The data byte is sent (or read) in two steps: first the 8 most significant bits, by a first validation on pin E, then the 4 least significant bits, by a second validation on pin E .</td></tr>
<tr><td rowspan="2">Technical specifications</td><td colspan="2">Microcontroller</td><td>ATmega1280</td><td>N°</td><td>Name</td><td>Role</td></tr>
<tr><td colspan="2">Operating Voltage</td><td>5V</td><td>1 à 8</td><td>DB7 à DB0</td><td>Data Bits</td></tr>
</table>

	Digital I/O Pins	54 (of which 15 provide PWM output)	**9**	IC1	Enable signal
	Input Voltage (limit)	6-20V	**10**	R/W	Read/Write H/L
	Analog Input Pins	**16**	**11**	RS	Selecting the register (command or data)
	DC Current per I/O Pin	40 mA	**12**	V0	Adjusting contrast
	DC Current for 3.3V Pin	50 mA	**13**	VSS	Ground
	Flash Memory	128 KB of which 4 KB used by bootloader	**14**	Vdd	+5V
	SRAM	28 KB	**15**	IC2	Enable signal

5.5 Assembling

In this chapter an overview will be giving of all the practical steps the team did to come up with the final miniature model.

1. Cutting the board
2. Painting the board
3. Reinstalling the old button board
4. Designing new cover sticker for the button board
5. Assembling the button board and model board in the frame
6. Assembling the electrical work
    a. Making the LEDs
    b. Connecting the buttons to the power supply
    c. Programming the Arduino
    d. Attaching the LCD screens and buttons to the Arduino
7. Attaching the models on the board
8. Attaching the pipelines
9. Finishing the frame with acrylic glass

5.4.1 Cutting the board

The old wooden board could not be reused because it had openings and holes from the old models which did not correspondent with the new model layout. Therefore it is decided to buy a new board and cut it in the right dimensions (124.5 mm by 95 mm) in order to fit properly in the frame. This is roughly done by a table saw and then perfected with a jig saw. The last step involved a sander to smoothen the edges.

5.4.2 Painting the board

Once the board is cut in the right dimensions, regular wall paint is bought at Clas Ohlson to paint the board. First a primer is applied. Using the 2D Autodesk Autocad sketch shown in Figure 23: 2D sketch, the correct layout is painted on the wooden board. An example of the plate is shown in Figure 73: Painting of wooden board. Each colour is applied in 2 layers, the painting itself takes only roughly fifteen minutes but in order to let it dry properly it is decided to paint over a time span of 4 days.

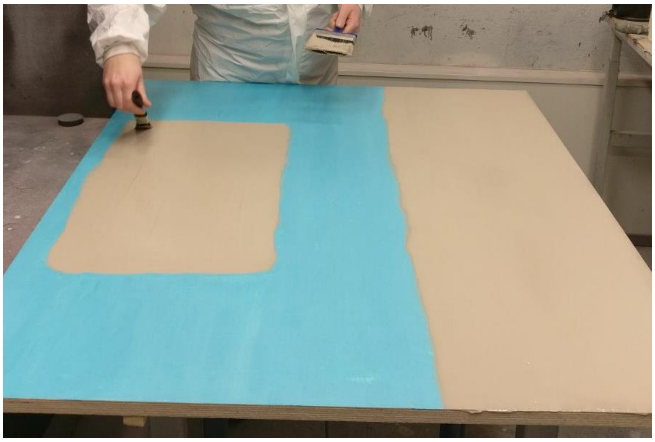


Figure 73: Painting of wooden board

5.4.3 Reinstalling the old button board

With the initial removal of the button board the side structure got damaged. In order to make it look good again, new parts are cut and attached. On top of that the remaining glue is taken off. After these improvements the buttons is screwed back in place. Progress can be seen in Figure 74: Old button board without buttons and Figure 75: Buttons still attached to the metal plate.

Figure 74: Old button board without buttons

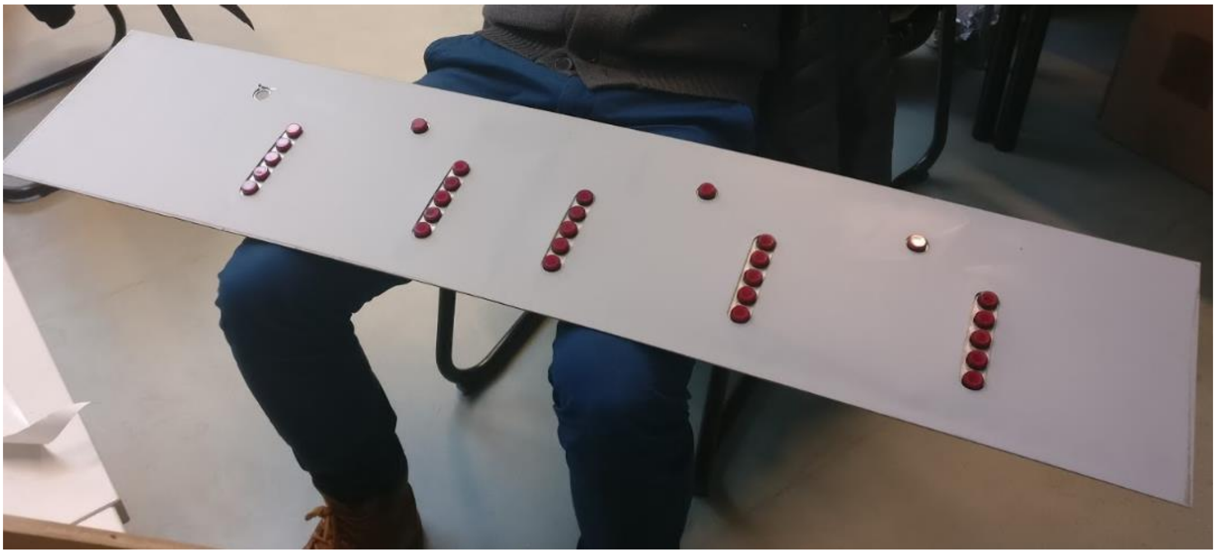


Figure 75: Buttons still attached to the metal plate

5.4.4 Designing the new cover sticker for the button board

The button board from the old model is used in the new model. The old button board is containing a wooden part and a metal plate. The metal plate is having holes to fit in the buttons. A sticker is attached to the metal plate. The sticker is containing the name for each step next to the corresponding button.

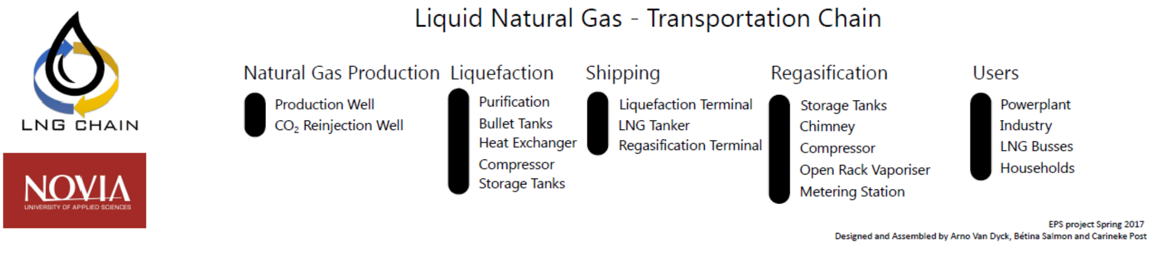


Figure 76: Sticker design

It should be easy to understand which button should be pushed to light up the right LED light, so the sticker should be clear and straight to the point. The designed sticker is shown in Figure 76: Sticker design. The black parts in the sticker are the place for the buttons, these are cut out during the printing. The metal plate is measured carefully to design the sticker with the correct size. On the left side the logo of the project and the logo of Novia University of Applied Sciences is placed to show the users the project team and the most important stakeholder: Novia University of Applied Sciences.

5.5.5 Assembling the button and model board in the frame

Once the buttons are screwed into place, the button board is installed in the frame using self-tapping screws. These screws fixed the wooden boards closely to the frame so no movement is possible. As an extra security two steel bolts are used to connect the button board to the rest of the frame.

5.5.6 Assembling the electrical work

All the electrical work is prepared theoretically to ensure fast assembly without mistakes could take place.

Firstly, the LEDs are soldered to the electrical wires and 680 ohm resistors are used to make sure the LEDs do not burn up. The LEDs are tested before permanently fixing them on the model. Making sure these worked properly all the wiring is prepared and all the buttons are tested one by one. When everything seemed to be in order the wires are glued together to the backside of the board.

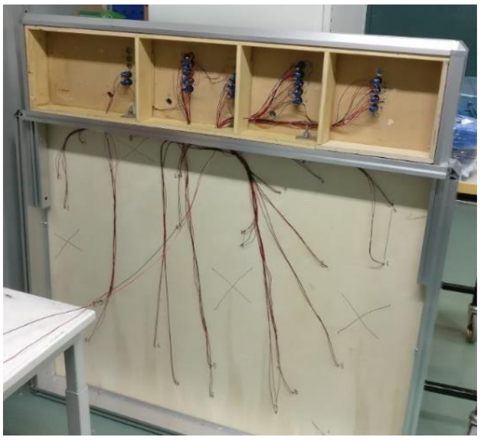


Figure 77: Glueing the button wires

The original power supply is not reused because it could only handle 0.3A and because the new model will use an Arduino and LCD screens it should be able to handle at least 2A. The old power supply is shown in Figure 78 The power supply of the old model. The new power supply is a prebuild converter 230V/12V which can handle up to 3A. The additional benefit of this power supply is that because it is prebuild there are no live wires that can be touched accidentally.

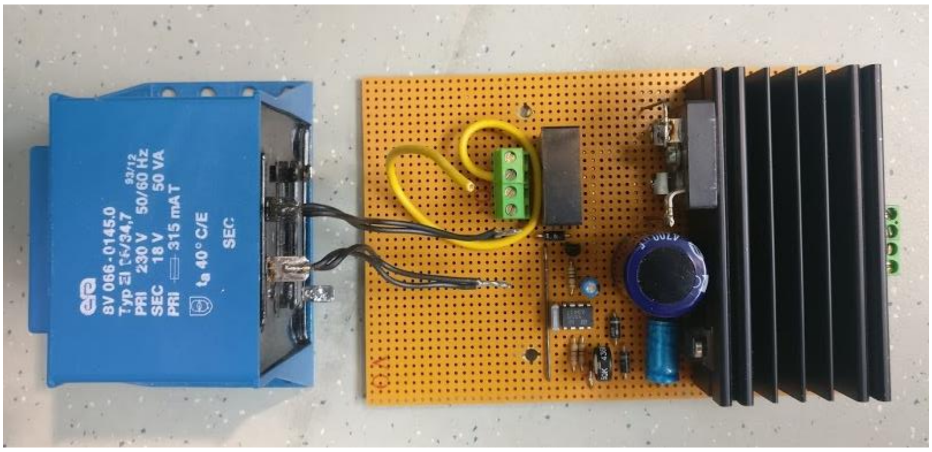


Figure 78 The power supply of the old model

5.5.7 Programming Arduino

The Arduino code can be divided into three main parts: *structure*, *values* (variables and constants), and *functions*. The description and the syntax is shown in Table 6 The description and syntax of the three main parts of the Arduino code.

The full code of the Arduino program is shown in appendix B

Table 6 The description and syntax of the three main parts of the Arduino code

Name of the functions	Description	Syntax

If / else if / else	This function allows the usage of multiple tests, for the project the analog entrances are tested. These entrances are buttons, if they are pressed, an action most occur.	if (buttonPressed[i] == 1 && buttonPrevious[i] != 1)
		{
		//do Thing A
		}
		else if (buttonPressed[i] == 0)
		{
		//do Thing B
		}
		else
		{
		//do Thing C
		}

LiquidCrystal()	This is a variable to use the screens.	LiquidCrystal(rs, rw, enable, d0, d1, d2, d3, d4, d5, d6, d7)
		
		#include <LiquidCrystal.h>
		
		LiquidCrystal lcd(12, 11, 10, 5, 4, 3, 2);
		
		void setup()
		{
		lcd.begin(16,1);
		lcd.print("hello, world!");
		}
		
		void loop() {}

Begin()	Initialises the interface to the LCD screen, and specifies the dimensions (width and height) of the display. `begin()` needs to be called before any other LCD library commands.	lcd.begin(columns, rows)
Clear()	Clears the LCD screen and positions the cursor in the upper-left corner	lcd.clear()
SetCursor():	Position the LCD cursor to the location at which subsequent text written to the LCD will be displayed.	lcd.setCursor(col, row)
Print():	Prints text to the LCD.	lcd.print(data) lcd.print(data, BASE)

5.5.8 Attaching LCD

The team first planned to cut out the holes for the screens and screw them in from the bottom. This way the circuit board is not visible when looking at the model. Unfortunately the plywood board is too thick (21mm) so the team is forced to screw the screens in from the top of the model. In order to get a clean look a LCD cover is designed. Thanks to this cover the circuit board is not visible anymore. The LCD cover is shown in Figure 79 The designed LCD cover.

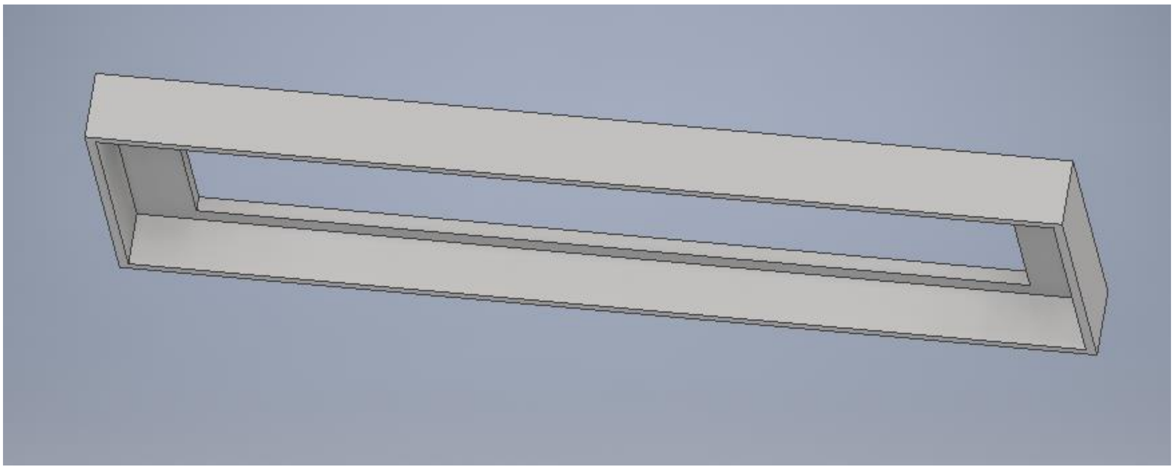


Figure 79 The designed LCD cover

The schematic shown in Figure 80 Schematic overview of the connections between the Arduino, LEDs and buttons is used to connect the LCD screens and the Arduino to the LEDs.

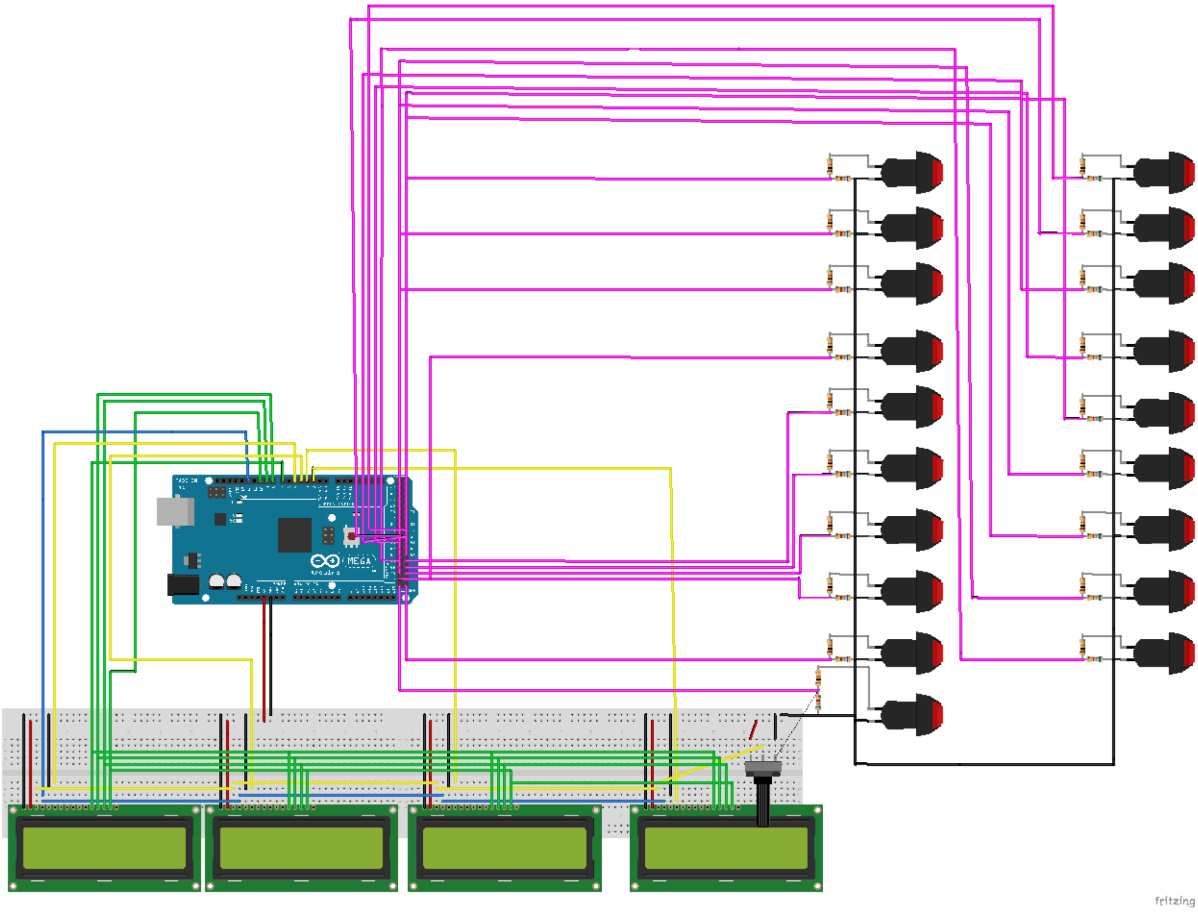


Figure 80 Schematic overview of the connections between the Arduino, LEDs and buttons

The following connections are used to connect the screens to the Mega:

A register select (RS) pin is controlling in which location on the LCD screens the data is written to. There is the choice to either select the data register, which holds what goes on the screen, or an instruction register, which is where the LCD screens controller looks for instructions on what to do next. This is attached to pin number 10.

A Read/Write (R/W) pin that selects reading mode or writing mode. This is attached to the pin number 9.

An Enable pin that enables writing to the registers. There are 2 enables pins, IC1 and IC2. There are attached to the pin number 8 and 11 for screen 1, 19 and 18 for screen 2 and 16 and 17 for screen 3. Enable pin IC1 enables the first two rows of the screen while IC2 enables line three and four.

8 data pins (D0 -D7). The states of these pins (high or low) are the bits that are written to a register, or the values that are read. The data pins are attached to pin number 14, 15, 2, 3, 4, 5, 6, 7.

Contrast pin (Vo): this is attached to pin number 12.

Power supply pins (+5V and Gnd): this is attached to pin number 14.

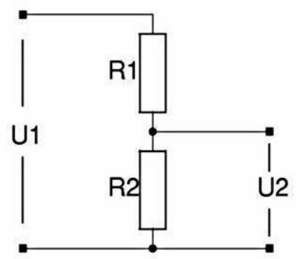
LED Backlight (Bklt+ and BKlt-) pins are used to power the LCD screens, control the display contrast, and turn on and off the LED backlight. These pins are attached to pin number 17 and 18.

The data which forms the image of what is desired to be displayed in the data registers is used for the display control process and then to put instructions in the instruction register. LCD screens compatible with Hitachi, this uses 8 bit modes, which requires 11 pins.

The following connections are used to connect the buttons to the Mega:

It was necessary to reduce the voltage of the buttons, because with the Mega card it is only possible to use 5V.

The voltages of the divider are connected to ground and the two resistors R1 and R2 are connected in series. A voltage U is input to these two resistors and the output voltage is measured across R2. A schematic overview of this is shown in Figure 81 The voltage divider circuit.



$$U2 = \frac{U1 * R2}{R1 + R2}$$

Figure 81 The voltage divider circuit

By using the law of the meshes and Ohm's law with the voltages U1 and U2, it is possible to deduce the relation between the output voltage U2 and the input voltage U:

$$U2 = \frac{U1 * R2}{R1 * R2}$$

$$5V = \frac{12\text{V} * \text{R2}}{10\ \text{k}\Omega + \text{R2}}$$

$$50\ k\Omega + 5R2 = 12R2$$

$$50k\ \Omega = 7R2$$

$$R2 = 7\ k\Omega$$

The first resistor is chosen random, in this project 10 kΩ is used. In order to have an output of 5V the calculations show that the second resistor has to be 7 kΩ. Unfortunately, 7 kΩ is not a standard resistor so 6.8k ohm resistors are used. A voltage divider board with two resistors welded for every button is used, which is shown in Figure 82 The front side of the voltage divider board and Figure 83 The backside of the voltage divider board . The 5V output voltage is wired to the Arduino, pin 30 to 48.

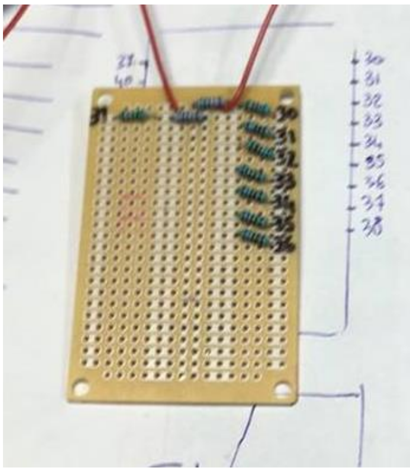


Figure 82 The front side of the voltage divider board

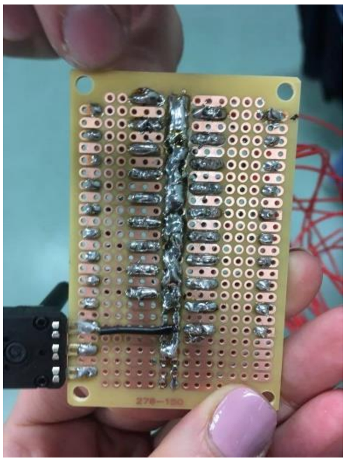


Figure 83 The backside of the voltage divider board

The text used for the LCD screens is shown in appendix C.

5.5.9 Attaching the models on the board

As soon as all the models are printed the team had to wait a couple days before installing the models. This is done in order to facilitate the installation of electrical components and wires. As soon as all components are fixed, the team used the 2D Autocad sketch, Figure 23: 2D sketch, to apply the printed models. This is done using a glue gun.

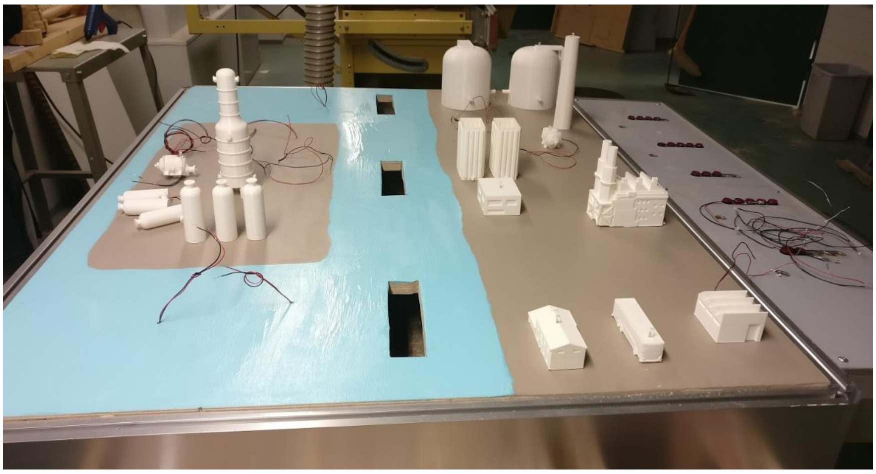


Figure 84: Attaching the models

5.5.10 Attaching pipelines

After all the models are attached the pipelines could be constructed. This is done using paper straws cut into right dimensions and then glued in the corresponding place. The yellow straws represent the gas flow, blue for liquefied gas and green for water and by-products.

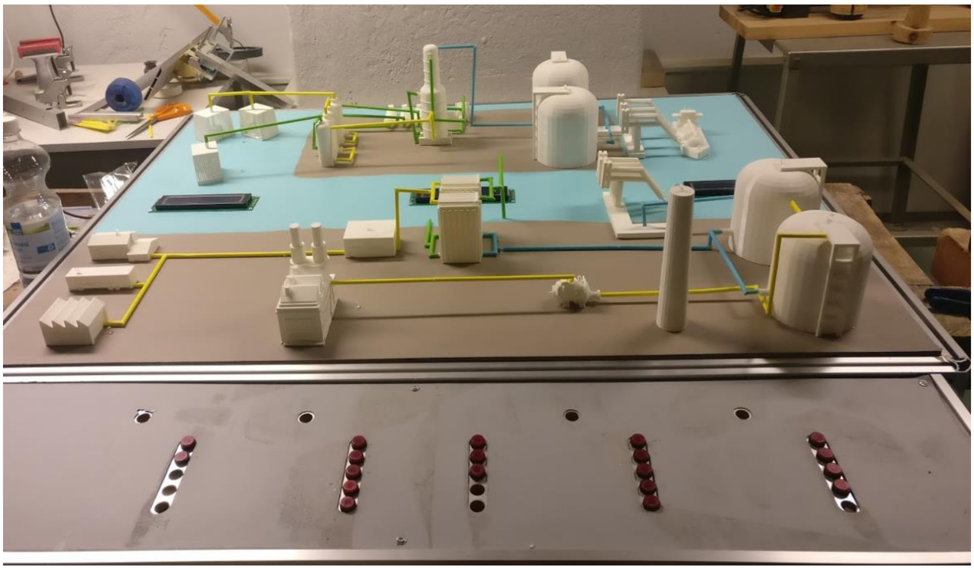


Figure 85: Attaching the pipelines

Once the pipelines are attached, all the LEDs are soldered to the corresponding buttons and tested it thoroughly, see Figure 86: Happy team members after the test was successful.

Figure 86: Happy team members after the test was successful

5.5.11 Finishing frame with acrylic glass

Once the electrical work, pipelines and models are installed the miniature model is tested so every LED lights up and the corresponding text comes on the right LCD screen. After finishing this crucial step the acrylic glass is mounted back on the frame to protect the model.

On top of a small wooden box on the backside of the board is designed as a place to let the adapter rest while transporting the model.

Last but not least the sticker is applied, this is the last step because then the risk of damaging the sticker is decreased.

5.5.12 QR code

In order to make the model usefull for everyone there is a QR code on the front pannel of the model. Using this code the user will be forwarded to a webpage where the user can test their newly gained knowledge. The sticker of the QR code is shown in Figure 87 The QR code to forwarded students to the test.

Test your knowledge

Room Name: LNGMODEL

Figure 87 The QR code to forwarded students to the test

6. The miniature model

After assembling all the parts of the model and make the electrical part work, the miniature is finished. Testing will be done to examine if the miniature model is meeting the requirements and a teacher manual is written for teachers who will use the model.

6.1 Testing

One of the more important goals of the project is that the model is educative. A test is done to examine if the model is increasing the level of knowledge of the students. The testing will go as followed:

1) The miniature model will be presented to the students of the EPS group. This will happen in a lecture format, so the EPS students will be treated like it is a real lecture.
2) After the lecture, the students have some time to explore the miniature model by themselves.
3) When the students got to know the miniature model it is time for a small test. This test is done with Socrative. Socrative is a website that teachers can use to make the lessons more active. It is possible to make tests, which students can make online by using a laptop or a smartphone. After the students finished the test the teacher can see the results of the test in a clear overview.
4) After everybody finished the test it is time to interpret the results and to see if the students understood the transportation chain of LNG.

6.1.1 Test

The test prepared with Socrative can be found in appendix D The test consist of ten questions, all related to a different step in the transportation chain. All the answers to the different questions can be found in the texts shown on the LCD screens.

To see if the miniature model is effective, the team decided to aim for an average score of 70%.

6.1.2 Results

The test is done by thirteen other EPS students. All of the students attended an introduction to the model and the students used the buttons to read the texts on the LCD screens. The average test results was 71.5%. This average score is higher than the score that was aimed for, which means the model is educative and students learn for it. The overview of the test results is shown in appendix E.

As can be seen in the overview of the test results in appendix E, some question score below 55%. The question with the lowest result is question 9: In which process step is Boil-off-gas formed? (more answers can be correct). The right answer is Storage and Shipping. Four of the students who had the wrong answer, just answered one of the answers. After asking the students the reasoning behind the answers, the students told us that it was not clear that more answers could be correct. Probably when the question or the answers are rephrased, more students would have given the right answer.

Question 2 had an average score of 53.8%. The question is: When is the LNG stored? For this question it was chosen to make the answers a little bit harder. There are 8 different options:

A. Before shipping the LNG
B. Before liquefaction

C. After shipping the LNG
D. During purification
E. Answers A and B are correct
F. Answers A and C are correct
G. Answers A, B, C and D are correct
H. Answers B and C are correct

The right answer is F. Which means that answer A and C are both correct as well. All the students who had given the wrong answer, answered with A or C. It can be assumed that the students knew the answer but did not read through all the answers, because there were too many questions.

Question 4 also had an average score of 53.8%. The question is: What is the typical shape of the storage vessels on the ship? The right answers is 'spherical'. The six students, who gave the wrong answer chose 'cylindrical'. After asking the students with the wrong answer the reasoning behind the answer, some of the students said it was not clear what the words mean or it was not clear if it was about the boat or the vessels on the boat. By adding pictures to the answers the difference between cylindrical and spherical could be clearer.

Overall, the result of the test is sufficient, which means the effect of the model on the knowledge of students is positive.

6.2 Teacher manual

The teacher manual is written to inform teachers about the theoretical background of the miniature model and about some technical details. The teacher manual can be found in appendix F.

7. Discussion

In this chapter the process to reach the final deadline will be discussed, this includes, the time management, the team work and the risks.

7.1 Time management

At the start of the project a Gantt chart is made, to track their achievements and make sure enough work is done to finish the project in time. As seen halfway through the project the team was right on schedule and planned to keep doing the work necessary to finish on time. When taking a look at the Gantt chart the team noticed it was not detailed enough to make the model perfect. Instead of spending more time to correct the planning the team decide not to use it anymore and put on some deadline on a piece of paper everybody had to respect. These deadlines were respected and the project was finished on time.

7.2 Risk management

The risk management is done during the project management part of the project. Since, the project is finished it is time to reflect on the risks.

7.2.1 Communication problems

During the project sometimes there were difficulties understanding each other because of the language barrier. When a team member did not understand what someone was trying to explain the team made sketches, plans, etc. to explain the problem until he/she understood what he/she was saying. A team member who does not fully knows what to do will slow down the process in the long term, or might even do useless or double work.

Philippe Fillatreau : "In order to be fast, take your time"

Overall there were some small problems with this but nothing major or no big misunderstandings.

7.2.2 Lack of software knowledge

At the start of the project no team members had previous knowledge of 3D drawing software. Thanks to the help of Sam Gevers and Euan Slevin, two members of the other LNG project, Arno Van Dyck quickly learned how to make the models. Because the team calculated enough time to design and print the models the impact of this risk was minimised.

Furthermore to control the LCD screens an Arduino MEGA was used. Again no team members had previous experience with Arduino so a lot of research was done. While working in the printing lab Arno Van Dyck got to know another Belgian exchange student, Dries Peeters, doing a project for VAMK. He was also using an Arduino to control his project so the team joined forces and fixed the problem together.

7.2.3 Lack of mechanical knowledge

The lack of mechanical knowledge, follows the previous one but is less likely to occur. The team had enough knowledge to install the LEDs and prepare the board so this was not a problem. The hardest part was getting everything to work together but after thorough research the team managed to make it work properly.

7.2.4 Too many/long trips

All the team members can include one trip organised by ESN in the semester. Unfortunately Bétina and Arno already booked two trips before that was known. To prevent the risk of losing too much time, extra work is done in the previous and following weeks.

7.2.5 Not enough material

When starting to prepare for the hardware work the team noticed there were not enough tools and paint available. Using the budget the team went to Clas Ohlson to buy the missing tools and paint. The risk had no impact except for the extra cost.

7.3 Team Work

During the course of the project the team got to know each other better and better. This made working together easier and it was known who could handle which workload. Because of the good team communications there were no fights or conflicts.

In appendix G is the time follow-up shown for each team member. As can be seen in the time follow-ups it can be concluded that the time spent on the project was equal for each team member.

8 Conclusion

The goal of this project was to build a miniature model that is showing the transportation chain of liquid natural gas. The model should be educative and interactive, so students wants to and do learn from it. Teachers should be able to use the model during lectures and the students should be able to use the model when it is situated in the corridor. According to the results of the test, it can be concluded that the effect of the model is as required. The average score of the test was 71.2%, which is above the aimed 70%. The LCD screens and the QR code make the model interactive and attractive to students.

Besides finishing a project, the main objective of EPS is training students to work together in a multi-cultural and multi-disciplinary groups. This project group is consisting of students with different nationalities, French, Dutch and Belgian, and with different backgrounds, namely electrical, chemical and industrial engineering. The group worked together well and all the members did learn something from the other group members. Thus, it can be concluded that the semester was a great success.

9 Bibliography

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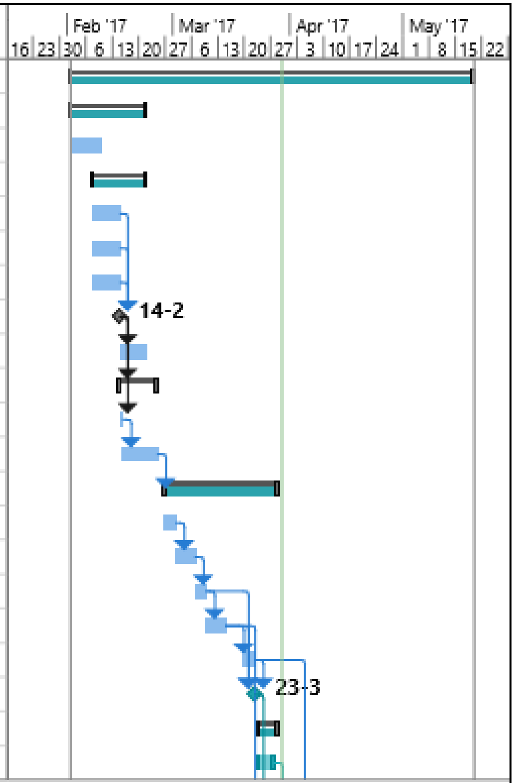
Appendix A

ID		Task Mode	Task Name	Duration	Start	Finish
1			**PROJECT**	**77 days**	**Thu 2-2-17**	**Fri 19-5-17**
2			**STUDY REPORT**	**14 days**	**Thu 2-2-17**	**Tue 21-2-17**
3			ANALYSE RISKS	4 days	Thu 2-2-17	Thu 9-2-17
4			**RESEARCH**	**10 days**	**Wed 8-2-17**	**Tue 21-2-17**
5			PRODUCTION OF NG	5 days	Wed 8-2-17	Tue 14-2-17
6			LIQUEFACTION	5 days	Wed 8-2-17	Tue 14-2-17
7			SHIPPING AND REGASIFICATION	5 days	Wed 8-2-17	Tue 14-2-17
8			OVERVIEW OF PROCESSES	0 days	Tue 14-2-17	Tue 14-2-17
9			SHAPE OF EQUIPEMENT	5 days	Wed 15-2-17	Tue 21-2-17
10			**SKETCH**	**8 days**	**Wed 15-2-17**	**Fri 24-2-17**
11			BRAINSTORM ROUGH SKETCH	1 day	Wed 15-2-17	Wed 15-2-17
12			STECHUP 3D SKETCH	7 days	Thu 16-2-17	Fri 24-2-17
13			**3D MODEL**	**22 days**	**Mon 27-2-17**	**Tue 28-3-17**
14			DIGITAL MODEL	3 days	Mon 27-2-17	Wed 1-3-17
15			HEAT EXCHANGERS	3 days	Thu 2-3-17	Mon 6-3-17
16			STORAGE TANKS	3 days	Tue 7-3-17	Thu 9-3-17
17			PURIFICATION STEPS	3 days	Fri 10-3-17	Tue 14-3-17
18			COMPRESSORS	3 days	Mon 20-3-17	Wed 22-3-17
19			EVERYTHING IS DESIGNED	0 days	Thu 23-3-17	Thu 23-3-17
20			**OLD MINIATURE**	**3 days**	**Fri 24-3-17**	**Tue 28-3-17**
21			DEINSTALLATION OLD MINIATURE	2 days	Fri 24-3-17	Mon 27-3-17

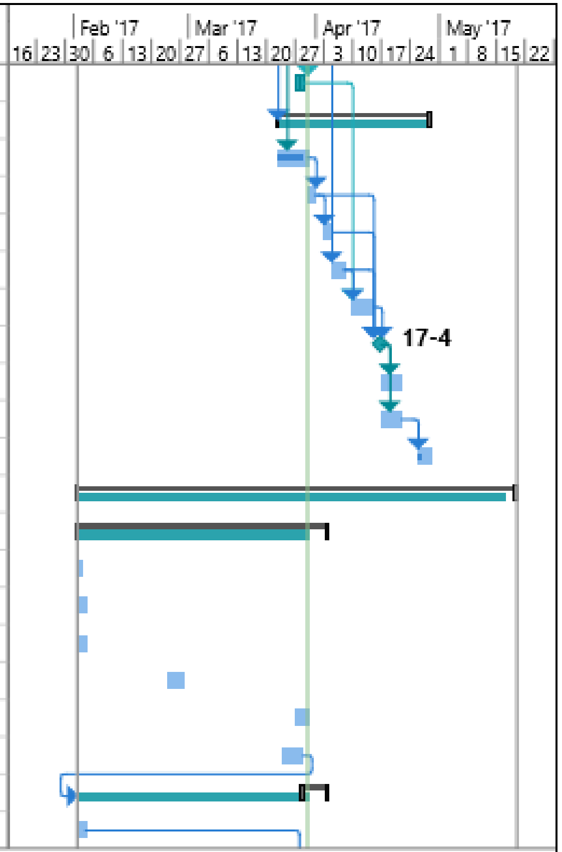


Project: Version 2.0
Date: Thu 30-3-17

Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Progress
Manual Progress

Page 1

ID	Task Mode	Task Name	Duration	Start	Finish
22		RECYCLING OLD PARTS	1 day	Tue 28-3-17	Tue 28-3-17
23		**MINIATURE**	**27 days**	**Thu 23-3-17**	**Fri 28-4-17**
24		3D PRINTING MODELS	5 days	Thu 23-3-17	Wed 29-3-17
25		INSTALLING PIPELINES	2 days	Thu 30-3-17	Fri 31-3-17
26		INSTALLING PUMPS / LED	2 days	Mon 3-4-17	Tue 4-4-17
27		MECHANICAL COMPONENTS	3 days	Wed 5-4-17	Fri 7-4-17
28		ELECTRICAL WORK	5 days	Mon 10-4-17	Fri 14-4-17
29		3D MODEL INSTALLED	0 days	Mon 17-4-17	Mon 17-4-17
30		DESIGNER'S MANUAL	5 days	Mon 17-4-17	Fri 21-4-17
31		TEACHER'S MANUAL	5 days	Mon 17-4-17	Fri 21-4-17
32		SURVEY	3 days	Wed 26-4-17	Fri 28-4-17
33		**EPS DOCUMENTS**	**77 days**	**Thu 2-2-17**	**Fri 19-5-17**
34		**MID-TERM REPORT**	**43 days**	**Thu 2-2-17**	**Mon 3-4-17**
35		INTRODUCTION	1 day	Thu 2-2-17	Thu 2-2-17
36		BRAINSTORM SESSIONS	2 days	Thu 2-2-17	Fri 3-2-17
37		BELBIN TEST	2 days	Thu 2-2-17	Fri 3-2-17
38		PROJECT OVERVIEW	2 days	Fri 24-2-17	Mon 27-2-17
39		CONCLUSION	3 days	Mon 27-3-17	Wed 29-3-17
40		FINALIZING THE MIDTERM REPORT	3 days	Fri 24-3-17	Tue 28-3-17
41		**MID-TERM PRESENTATION**	**4 days**	**Wed 29-3-17**	**Mon 3-4-17**
42		MAKING SLIDES	2 days	Thu 2-2-17	Fri 3-2-17

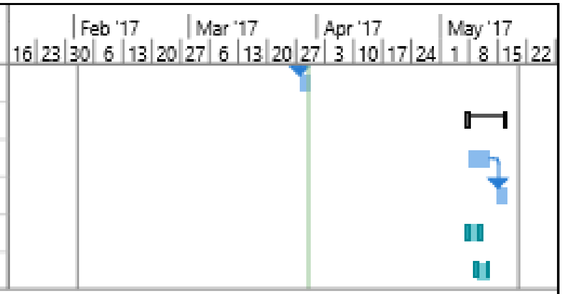


Task		Inactive Summary		External Tasks	
Split		Manual Task		External Milestone	
Milestone		Duration-only		Deadline	
Summary		Manual Summary Rollup		Progress	
Project Summary		Manual Summary		Manual Progress	
Inactive Task		Start-only			
Inactive Milestone		Finish-only			

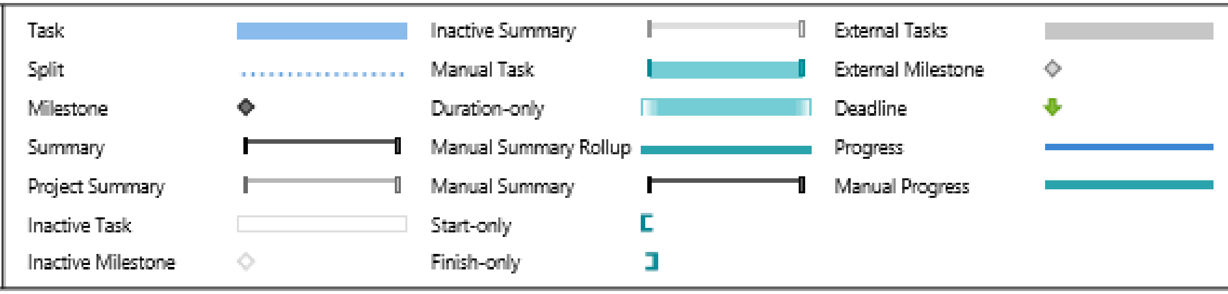
Project: Version 2.0
Date: Thu 30-3-17

Page 2

ID		Task Mode	Task Name	Duration	Start	Finish
43			PREPARING PRESENTATION TALK	2 days	Tue 28-3-17	Wed 29-3-17
44			**FINAL PROJECT**	**7 days**	**Mon 8-5-17**	**Tue 16-5-17**
45			FINAL REPORT	5 days	Mon 8-5-17	Fri 12-5-17
46			FINAL PRESENTATION	2 days	Mon 15-5-17	Tue 16-5-17
47			EPS Movie	3 days	Mon 8-5-17	Wed 10-5-17
48			Website	3 days	Wed 10-5-17	Fri 12-5-17



Project: Version 2.0
Date: Thu 30-3-17



Page 3

Appendix B

```
#include <LiquidCrystal.h>


// screen 1:

LiquidCrystal lcd0 (10, 9, 8, 14, 15, 2, 3, 4, 5, 6, 7);

 //11(RS), 10(R/W), 9(IC1), 8(DB0), 7(DB1), 6(DB2), 5(DB3), 4(DB4), 3(DB5), 2(DB6), 1(BD7).

LiquidCrystal lcd1 (10, 9, 11, 14, 15, 2, 3, 4, 5, 6, 7);

//11(RS), 10(R/W), 15(IC2), 8(DB0), 7(DB1), 6(DB2), 5(DB3), 4(DB4), 3(DB5), 2(DB6), 1(BD7).


// screen 2:

LiquidCrystal lcd2 (10, 9, 19, 14, 15, 2, 3, 4, 5, 6, 7);

 //11(RS), 10(R/W), 9(IC1), 8(DB0), 7(DB1), 6(DB2), 5(DB3), 4(DB4), 3(DB5), 2(DB6), 1(BD7).

LiquidCrystal lcd3 (10, 9, 18, 14, 15, 2, 3, 4, 5, 6, 7);

//11(RS), 10(R/W), 15(IC2), 8(DB0), 7(DB1), 6(DB2), 5(DB3), 4(DB4), 3(DB5), 2(DB6), 1(BD7).


// screen 3:

LiquidCrystal lcd4 (10, 9, 16, 14, 15, 2, 3, 4, 5, 6, 7);

//11(RS), 10(R/W), 9(IC1), 8(DB0), 7(DB1), 6(DB2), 5(DB3), 4(DB4), 3(DB5), 2(DB6), 1(BD7).

LiquidCrystal lcd5 (10, 9, 17, 14, 15, 2, 3, 4, 5, 6, 7);

//11(RS), 10(R/W), 15(IC2), 8(DB0), 7(DB1), 6(DB2), 5(DB3), 4(DB4), 3(DB5), 2(DB6), 1(BD7).



// set up a constant for the tilt switchPin:

const int switchPin1 = 30;

const int switchPin2 = 31;

const int switchPin3 = 32;

const int switchPin4 = 33;

const int switchPin5 = 34;
```

```
const int switchPin6 = 35;
const int switchPin7 = 36;
const int switchPin8 = 37;
const int switchPin9 = 38;
const int switchPin10 = 39;
const int switchPin11 = 40;
const int switchPin12 = 41;
const int switchPin13 = 42;
const int switchPin14 = 43;
const int switchPin15 = 44;
const int switchPin16 = 45;
const int switchPin17 = 46;
const int switchPin18 = 47;
const int switchPin19 = 48;

const int buttonArray[19] =
{switchPin1,switchPin2,switchPin3,switchPin4,switchPin5,switchPin6,switchPin7,switchPin8,switchPi
n9,switchPin10,switchPin11,switchPin12,switchPin13,switchPin14,switchPin15,switchPin16,switchPi
n17,switchPin18,switchPin19};
int buttonPressed[19] ={0};
int buttonPrevious[19] ={0};

long previousMillis = 0;
long interval = 10000;

void setup()
{
 lcd0.begin(40,2);
 lcd1.begin(40,2);
 lcd2.begin(40,2);
```

```
 lcd3.begin(40,2);
 lcd4.begin(40,2);
 lcd5.begin(40,2);
}

void loop()
{
 for(int i = 0; i < 19; i++)
 {
  if(digitalRead(buttonArray[i]) == HIGH)
  {
   buttonPressed[i] = 1;
  }
  else
  {
   buttonPressed[i] = 0;
  }
 }

 for(int i = 0; i < 19; i++)
 {
  switch(buttonArray[i])
  {
   case switchPin1: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){

                   buttonPrevious[i] = 1;
                  }
                  else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
                  {
```

```
          lcd2.clear();
          lcd3.clear();
          lcd2.print("The boil-off-gas will be                     converted ");
          lcd2.setCursor(0,1);
          lcd2.print("in to power by the                           power
plant.");
          lcd2.setCursor(0,1);
          lcd3.print("This power can be used in the           LNG");
          lcd3.setCursor(0,1);
          lcd3.print(" process.");

          buttonPrevious[i] = 1;
          buttonPrevious[i] =1;
         }
         else if(buttonPressed[i] == 0)
         {
          buttonPrevious[i] == 0;
         }
         break;

   case switchPin2: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
          lcd2.clear();
          lcd3.clear();

          lcd2.print("The industry is one of the users             of natural
gas.");
          lcd2.setCursor(0,1);

          buttonPrevious[i] = 1;
```

```
}
else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
{
  buttonPrevious[i] =1;
}
else if(buttonPressed[i] == 0)
{
  buttonPrevious[i] == 0;
}
break;
case switchPin3: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
  lcd2.clear();
  lcd3.clear();
 lcd2.print("Special buses can use NG as fuel                    insteadof
traditional fuels.");
  lcd2.setCursor(0,1);
  lcd3.print("");
  lcd3.setCursor(0,1);
  buttonPrevious[i] = 1;
}
else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
{
  buttonPrevious[i] =1;
}
else if(buttonPressed[i] == 0)
{
  buttonPrevious[i] == 0;
}
break;
```

```
case switchPin4: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
            lcd2.clear();
            lcd3.clear();
             lcd2.print("Households can use the natural                    gas to");
            lcd2.setCursor(0,1);
            lcd2.print("heat their houses and to cook                  on.");
            lcd3.setCursor(0,1);
            buttonPrevious[i] = 1;
           }
           else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
           {
            buttonPrevious[i] =1;
           }
           else if(buttonPressed[i] == 0)
           {
            buttonPrevious[i] == 0;
           }
           break;
case switchPin5: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
            lcd0.clear();
            lcd1.clear();
            lcd0.print("The LNG is stored after shipping                    in the ");
            lcd0.setCursor(0,1);
            lcd0.print("same kind of tanks as before                        shipping.");
            lcd0.setCursor(0,1);
            lcd1.print("During storage, Boil-off-gas                        can");
            lcd1.setCursor(0,1);
            lcd1.print("be formed due to increase in
temperature");
```

```
        buttonPrevious[i] = 1;
      }
      else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
      {
        buttonPrevious[i] =1;
      }
      else if(buttonPressed[i] == 0)
      {
        buttonPrevious[i] == 0;
      }
      break;
  case switchPin6: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
        lcd0.clear();
        lcd1.clear();
        lcd0.print("The chimney is used to burn                    the");
        lcd0.setCursor(0,1);
        lcd0.print("unwanted boil-off-gas. This is                 not");
        lcd0.setCursor(0,1);
        lcd1.print("preferable, because it will send                ");
        lcd1.setCursor(0,1);
        lcd1.print("greenhouse gasses in the
atmosphere.");
        buttonPrevious[i] = 1;
      }
      else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
      {
        buttonPrevious[i] =1;
      }
      else if(buttonPressed[i] == 0)
```

```
{
 buttonPrevious[i] == 0;
}
break;
case switchPin7: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
 lcd0.clear();
 lcd1.clear();
 lcd0.print("Preferably, the boil-off-gas                          will be");
 lcd0.setCursor(0,1);
 lcd0.print("used in a powerplant. ");
 lcd0.setCursor(0,1);
 lcd1.print("Before this is possible the gas                   will be");
 lcd1.setCursor(0,1);
 lcd1.print("compressed in the compressor.");
 lcd1.setCursor(0,1);

 buttonPrevious[i] = 1;
}
else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
{
 buttonPrevious[i] =1;
}
else if(buttonPressed[i] == 0)
{
 buttonPrevious[i] == 0;
}
break;
case switchPin8: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
 lcd0.clear();
```

```
            lcd1.clear();
            lcd0.print("An open-rack-vaporiser is a                         heat");
            lcd0.setCursor(0,1);
            lcd0.print("exchanger which is using                            seawater
to");
            lcd0.setCursor(0,1);
            lcd1.print("heat up the LNG to make the LNG                     gaseous.");
            lcd1.setCursor(0,1);
            lcd1.print("");
            buttonPrevious[i] = 1;
           }
           else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
           {
            buttonPrevious[i] =1;
           }
           else if(buttonPressed[i] == 0)
           {
            buttonPrevious[i] == 0;
           }
           break;
   case switchPin9: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
            lcd0.clear();
            lcd1.clear();

            lcd0.print("In the metering station the                         quality ");
            lcd0.setCursor(0,1);
            lcd0.print("and quantity of the natural gas                     ");
            lcd0.setCursor(0,1);
            lcd1.print("is measured. From the metering                      station ");
```

```
 lcd1.setCursor(0,1);
 lcd1.print("the natural gas is send to the                         users.");
 buttonPrevious[i] = 1;
}
else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
{
 buttonPrevious[i] =1;
}
else if(buttonPressed[i] == 0)
{
 buttonPrevious[i] == 0;
}
break;
case switchPin10: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){

 lcd4.clear();
 lcd5.clear();

 lcd4.print("The LNG is pumped into the LNG                         tanker. ");
 lcd4.setCursor(0,1);
 lcd4.print("The LNG can be shipped.");
 lcd5.setCursor(0,1);
 buttonPrevious[i] = 1;
}
else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
{
 buttonPrevious[i] =1;
}
else if(buttonPressed[i] == 0)
```

```
            {
             buttonPrevious[i] == 0;
            }
            break;
    case switchPin11: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
             lcd4.clear();
             lcd5.clear();

             lcd4.print("The LNG is shipped with a LNG                    tanker.");
             lcd4.setCursor(0,1);
             lcd4.print("The spherical tanks are isolated                 to ");
             lcd5.print("stabilise the temperature,");
             lcd5.setCursor(0,1);
             lcd5.print("so no boil-off gas is formed.");

             buttonPrevious[i] = 1;
            }
            else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
            {
             buttonPrevious[i] =1;
            }
            else if(buttonPressed[i] == 0)
            {
             buttonPrevious[i] == 0;
            }
            break;
    case switchPin12: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
             lcd4.clear();
             lcd5.clear();
```

```
            lcd4.print("The LNG is received in the                          terminal.");
            lcd4.setCursor(0,1);
            buttonPrevious[i] = 1;
          }
          else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
          {
            buttonPrevious[i] =1;
          }
          else if(buttonPressed[i] == 0)
          {
            buttonPrevious[i] == 0;
          }
          break;

    case switchPin13: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
            lcd0.clear();
            lcd1.clear();

            lcd0.print("The CO2, H2O and H2S in the                          natural
gas");
            lcd0.setCursor(0,1);
            lcd0.print("are impurities, which needs to                       be");
            lcd0.setCursor(0,1);
            lcd1.print("removed.The impurities will be                       removed");
            lcd1.setCursor(0,1);
            lcd1.print("by the purification tanks.");
            lcd1.setCursor(0,1);
            buttonPrevious[i] = 1;
```

```
}
else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
{
 buttonPrevious[i] =1;
}
else if(buttonPressed[i] == 0)
{
 buttonPrevious[i] == 0;
}
break;
case switchPin14: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
 lcd0.clear();
 lcd1.clear();

 lcd0.print("The H2O and H2S removed by                              the");
 lcd0.setCursor(0,1);
 lcd0.print("purification step is stored in                     the");
 lcd0.setCursor(0,1);
 lcd1.print("bullet tanks.");
 lcd1.setCursor(0,1);
 lcd1.print("These can be sold seperately.");
 lcd1.setCursor(0,1);
 buttonPrevious[i] = 1;
}
else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
{
 buttonPrevious[i] =1;
}
else if(buttonPressed[i] == 0)
```

```
{
  buttonPrevious[i] == 0;
}
break;
case switchPin15: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
  lcd0.clear();
  lcd1.clear();

  lcd0.print("The natural gas is cooled to -                    162 C by a");
  lcd0.setCursor(0,1);
  lcd0.print("heat exchanger, that is                    cryogenic
and");
  lcd0.setCursor(0,1);
  lcd1.print("has two refrigerant circuits. By                    cooling");
  lcd1.setCursor(0,1);
  lcd1.print("the natural gas is turned into a                    liquid.");

  buttonPrevious[i] = 1;
}
else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
{
  buttonPrevious[i] =1;
}
else if(buttonPressed[i] == 0)
{
  buttonPrevious[i] == 0;
}
break;
case switchPin16: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
```

```
        lcd0.clear();
        lcd1.clear();

        lcd0.print("The compressor is used to                    stabilise
the");
        lcd0.print("temperature and the pressure of              the");
        lcd0.setCursor(0,1);
        lcd1.print("refrigerant.");
        lcd1.setCursor(0,1);
        buttonPrevious[i] = 1;
       }
       else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
       {
        buttonPrevious[i] =1;
       }
       else if(buttonPressed[i] == 0)
       {
        buttonPrevious[i] == 0;
       }
       break;
   case switchPin17: If(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
        lcd0.clear();
        lcd1.clear();

              lcd0.print("The LNG is stored before
shipping.");
        lcd0.setCursor(0,1);
        lcd0.print("The flat-bottom tanks are                    isolated to");
        lcd0.setCursor(0,1);
```

```
        lcd1.print("ensure the temperature inside                     the tank.");
        lcd1.setCursor(0,1);
        lcd1.print("");

        buttonPrevious[i] = 1;
       }
       else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
       {
        buttonPrevious[i] =1;
       }
       else if(buttonPressed[i] == 0)
       {
        buttonPrevious[i] == 0;
       }
       break;
   case switchPin18: If(buttonPressed[i] == 1 && buttonPrevious[i] != 1){
        lcd2.clear();
        lcd3.clear();

        lcd2.print("The natural gas is extracted                          from the
earth by the pumps. ");
        lcd2.setCursor(0,1);
        lcd3.print("The main component of the                             natural gas
ismethane. Location: Snohvit,                  Norway. ");
        lcd3.setCursor(0,1);
        buttonPrevious[i] = 1;
       }
       else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
       {
```

```
          buttonPrevious[i] =1;
        }
        else if(buttonPressed[i] == 0)
        {
          buttonPrevious[i] == 0;
        }
        break;
  case switchPin19: if(buttonPressed[i] == 1 && buttonPrevious[i] != 1){

          lcd2.clear();
          lcd3.clear();

          lcd2.print("The CO2 removed from natural gas                  is ");
          lcd2.setCursor(0,1);
          lcd2.print("pumped back into the earth.");
          lcd3.setCursor(0,1);
          buttonPrevious[i] = 1;
        }
        else if(buttonPressed[i] == 1 && buttonPrevious[i] == 1)
        {
          buttonPrevious[i] =1;
        }
        else if(buttonPressed[i] == 0)
        {
          buttonPrevious[i] == 0;
        }
        break;
  default:
      lcd0.clear();
```

```
            lcd1.clear();
            lcd2.clear();
            lcd3.clear();
            lcd4.clear();
            lcd5.clear();
         break;
      }
    }

    unsigned long currentMillis = millis();

  if(currentMillis - previousMillis > interval)
  {
    previousMillis = currentMillis;

    lcd0.clear();
    lcd1.clear();
    lcd2.clear();
    lcd3.clear();
    lcd4.clear();
    lcd5.clear();
    for(int i = 0; i < 19 ; i++)
    {
      buttonPrevious[i] = 0;
      buttonPressed[i] = 0;
    }
  }

      }
```

Appendix C

Button	Text
Production well	The natural gas is extracted from the earth by the pumps. The main component of the natural gas is methane. Location: Snøhvit, Norway
CO_2 well	The CO_2 removed from natural gas is pumped back into the earth.
Purification process	The CO_2, H_2O and H_2S in the natural gas are impurities, which need to be removed. The impurities will be removed by the purification tanks.
Heat exchangers	The natural gas is cooled to -162°C by a heat exchanger, that is cryogenic and has two refrigerant circuits. By cooling the natural gas is turned into a liquid.
Refrigerant compressor	The compressor is used to stabilise the temperature and the pressure of the refrigerant.
Storage tanks	The LNG is stored before shipping. The flat-bottom tanks are isolated to ensure the temperature inside the tank.
Liquefaction terminal	The LNG is pumped into the LNG tanker. The LNG can be shipped
LNG tanker	The LNG is shipped with a LNG tanker. The spherical tanks are isolated to stabilise the temperature. The temperature can increase which results in boil-off-gas.
Regasification terminal	The LNG is received in the terminal.
Storage tank	The LNG is stored after shipping in the same kind of tanks as before shipping. During storage, Boil-off-gas can be formed due to increase in temperature.
Chimney	The chimney is used to burn the unwanted boil-off-gas. This is not preferable, because it will send greenhouse gasses in the atmosphere.
Boil-off compressor	Preferably, the boil-off-gas will be used in a powerplant. Before this is possible the gas will be compressed in the compressor.
Open rack vaporiser	An open-rack-vaporiser is a heat exchanger which is using seawater to heat up the LNG to make the LNG gaseous.
Metering station	In the metering station the quality and quantity of the natural gas is measured. From the metering station the natural gas is sent to the users.

Industry	Industry is one of the users of natural gas
LNG buses	Special buses can use NG as fuel instead of traditional fuels.
Households	Households can use the natural gas to heat their houses and to use as a cooking fuel.
Bullet tank	The H_2O and H_2S removed by the purification step is stored in the bullet tanks. This can be sold separately .
Powerplant	The boil-off-gas will be converted in to power by the powerplant. This power can be used in the LNG process.

Appendix D

socrative
by MasteryConnect

EPS - LNG miniature model Score:

1. **What is the first physical transformation the natural gas is going through in the process?**
   - (A) Liquefaction: going from gas phase to liquid phase
   - (B) Regasification: going from liquid phase to gas phase
   - (C) Melting: going from solid phase to liquid phase

2. **When is the LNG stored?**
   - (A) Before shipping the LNG
   - (B) Before liquefaction
   - (C) After shipping the LNG
   - (D) During purification
   - (E) Answers A and B are correct
   - (F) Answers A and C are correct
   - (G) Answers A, B, C and D are correct
   - (H) Answers B and C are correct

3. **What are the three main users of natural gas?**
   - (A) Households
   - (B) Farms
   - (C) Busses
   - (D) Electrical bikes
   - (E) Harbours
   - (F) Industry
   - (G) Construction companies

4. **What is the typical shape of the storage vessels on the ship?**
   - (A) Cylinderical
   - (B) Pyramidal
   - (C) Spherical

5. **What is the advantage of Liquid Natural Gas over Natural Gas?**
   - (A) The LNG is more flammable than the natural gas
   - (B) The liquid natural gas is having a lower volume
   - (C) The conduction of LNG is higher than of Natural Gas
   - (D) Less energy is required for the production
   - (E) There is no advantage

Page 1 of 2

6. **Which process step is essential before liquefaction?**

- (A) Distillation
- (B) Pasteurisation
- (C) Purification
- (D) Sterilisation
- (E) Emulsification

7. **What is the main component of natural gas?**

- (A) Butane
- (B) Propane
- (C) Carbohydrates (length C12-C16)
- (D) Methane
- (E) Carbohydrates (length C4-C12)
- (F) Carbon dioxide

8. **What three components are removed during the purification step?**

- (A) Iron - Mercury - Sodium
- (B) Carbon dioxide - Water - Hydrogen sulphide
- (C) Hydrogen gas - Bacteria - Methane
- (D) Chlorine - Bromide - Fluoride

9. **In which process step is Boil-off-gas formed? (more answers can be correct)**

- (A) Storage
- (B) Regasification
- (C) Production
- (D) Shipping

10. **What is the purpose of the chimney?**

- (A) Evaporating the cooling water
- (B) Burning off the unwanted boil-off-gas
- (C) Investigating the energy density of the natural gas
- (D) Burning off the refrigerant used in liquefaction
- (E) Producing energy used in the regasification

Appendix E

	Total Score (0 - 100)	Number of correct answers	What is the first physical transformation the natural gas is going through in the process?	When is the LNG stored?	What are the three main users of natural gas?	What is the typical shape of the storage vessels on the ship?	What is the advantage of Liquid Natural Gas over Natural Gas?
1	50	5	Liquefaction: going from gas phase to liquid phase	After shipping the LNG	Households, Buses, Industry	Cylinderical	The LNG is more flammable than the natural gas
2	70	7	Liquefaction: going from gas phase to liquid phase	Answers A and C are correct	Households, Industry, Construction companies	Cylinderical	The liquid natural gas is having a lower volume
3	50	5	Liquefaction: going from gas phase to liquid phase	Before shipping the LNG	Households, Buses, Industry	Cylinderical	The liquid natural gas is having a lower volume
4	100	10	Liquefaction: going from gas phase to liquid phase	Answers A and C are correct	Households, Buses, Industry	Spherical	The liquid natural gas is having a lower volume
5	60	6	Liquefaction: going from gas phase to liquid phase	Answers B and C are correct	Households, Buses, Industry	Cylinderical	The liquid natural gas is having a lower volume
6	90	9	Liquefaction: going from gas phase to liquid phase	Before shipping the LNG	Households, Buses, Industry	Spherical	The liquid natural gas is having a lower volume
7	70	7	Liquefaction: going from gas phase to liquid phase	Answers A and C are correct	Households, Buses, Industry	Spherical	Less energy is required for the production
8	70	7	Liquefaction: going from gas phase to liquid phase	After shipping the LNG	Households, Buses, Industry	Spherical	The liquid natural gas is having a lower volume
9	60	6	Liquefaction: going from gas phase to liquid phase	Answers A and C are correct	Households, Industry, Construction companies	Cylinderical	The liquid natural gas is having a lower volume
10	80	8	Liquefaction: going from gas phase to liquid phase	Answers A and C are correct	Households, Buses, Industry	Spherical	The liquid natural gas is having a lower volume
11	50	5	Liquefaction: going from gas phase to liquid phase	After shipping the LNG	Households, Buses, Industry	Cylinderical	The liquid natural gas is having a lower volume
12	90	9	Liquefaction: going from gas phase to liquid phase	Answers A and C are correct	Households, Buses, Industry	Spherical	The liquid natural gas is having a lower volume
13	90	9	Liquefaction: going from gas phase to liquid phase	Answers A and C are correct	Households, Buses, Industry	Spherical	The liquid natural gas is having a lower volume
Cla	71.5%	7.15	100.0%	80.8%	84.6%	53.8%	84.6%

	Which process step is essential before liquefaction?	What is the main component of natural gas?	What three components are removed during the purification step?	In which process step is Boil-off-gas formed? (more answers can be correct)	What is the purpose of the chimney?
1	Purification	Methane	Carbon dioxide - Water - Hydrogen sulphide	Storage	Evaporating the cooling water
2	Purification	Methane	Carbon dioxide - Water - Hydrogen sulphide	Regasification	Burning off the unwanted boil-off-
3	Purification	Carbon dioxide	Carbon dioxide - Water - Hydrogen sulphide	Regasification, Production	Evaporating the cooling water
4	Purification	Methane	Carbon dioxide - Water - Hydrogen sulphide	Storage, Shipping	Burning off the unwanted boil-off-
5	Purification	Methane	Iron - Mercury - Sodium	Storage	Burning off the unwanted boil-off-
6	Purification	Methane	Carbon dioxide - Water - Hydrogen sulphide	Storage, Shipping	Burning off the unwanted boil-off-
7	Purification	Carbon dioxide	Carbon dioxide - Water - Hydrogen sulphide	Regasification	Burning off the unwanted boil-off-
8	Purification	Methane	Carbon dioxide - Water - Hydrogen sulphide	Regasification	Burning off the refrigerant used in liquefaction
9	Sterilisation	Methane	Carbon dioxide - Water - Hydrogen sulphide	Regasification, Production	Burning off the unwanted boil-off-
10	Purification	Methane	Carbon dioxide - Water - Hydrogen sulphide	Regasification	Burning off the refrigerant used in liquefaction
11	Purification	Methane	Hydrogen gas - Bacteria - Methane	Shipping	Evaporating the cooling water
12	Purification	Methane	Carbon dioxide - Water - Hydrogen sulphide	Storage, Regasification	Burning off the unwanted boil-off-gas
13	Purification	Methane	Carbon dioxide - Water - Hydrogen sulphide	Storage	unwanted boil-off-gas
Class	92.3%	84.6%	84.6%	15.4%	61.5%

Appendix F

LNG miniature model

Teacher's manual

Table of contents

Overview

Because LNG is an upcoming energy tool more knowledge is required. This model will provide Novia University with a tool to educate students about the transportation of LNG. Because the model is interactive and self-explanatory there is no need for a teacher to be present at all times. Although it is interesting for a teacher to give them a brief demonstration of the model to spike the students interests. Later on students can experiment independently to let the information sink in even more. This manual includes a 10 question test to check whether the students fully understood the information that is given using the model.

Objectives

Students will

- Know how LNG gas is produced
- Understand the different steps of the liquefaction, and know why this step is crucial
- Have basic knowledge of the shipping of LNG
- Understand the different steps of the regasification process
- Understand how to store LNG and the difficulties that arise with storing LNG.
- Have a feeling about possible end-users

In summary, a global overview of the different steps of the LNG chain of value.

Time requirements

Preparation will take approximately 5 minutes. This includes making sure the model is plugged in and the previous students left the model with clear LCD screens and un-pressed buttons. If the buttons are pressed simply press them again to turn of the LEDs so the next students can start with a clear model. Every 20 seconds the screens will turn clear if no buttons are pressed.

Demonstration will take around 15 minutes depending on the size of the group. An ideal group wouldn't exceed 10 students so they can all gather around the model without obstructing each other's view. After the demonstration is given students can further experiment with the model in smaller groups or in between classes when walking in the hallway.

Errors

An error that might occur is, when two different parts of the process use the same screen (e.g. liquefaction and regasification) the screen could display the wrong text. To fix this the buttons of the previous part (e.g. liquefaction) should be turned off and then followed by pressing the buttons on the next part (e.g. regasification).

If a student presses the next step in the process flow this text message will be given priority and replace the previous message. In case someone wants to read the previous one again the later button should be unpressed and you have to wait until the reset occurs in order to get the right message up again.

The button of the powerplant has a problem, when pressing it the LED will burn but only the first line of text will show. In order to show the full text unpress the button again.

Different stages of the model

In this paragraph all different steps will be explained, this is very briefly summarised on the LCD screens as can be seen in the next chapter. The information given is the most general approach, there can be different approaches in other companies around the world. In order to educate the students as good as possible the teacher should give this information when demonstrating the model.

Production

The production of liquid natural gas finds place in Snøhvit, Norway. This is the most northern situated offshore gas production plant. The location can be seen in Figure 88:Location of Snøhvit on the map of Norway. The gas is extracted from the subsea with a capacity of 17.000 m^3 natural gas per day. This gas is transported to Melkoya, a small island on the shore of Norway next to Hammerfest. During extraction of the natural gas a lot of carbon dioxide will be extracted together with the natural gas. Instead of releasing this useless carbon dioxide in the atmosphere they extract it and pump it back to Snøhvit. Here is the carbon dioxide injected back into the ground below the gas-bearing formation. This technique reduces the CO2 emission by 700.000 tons per year.

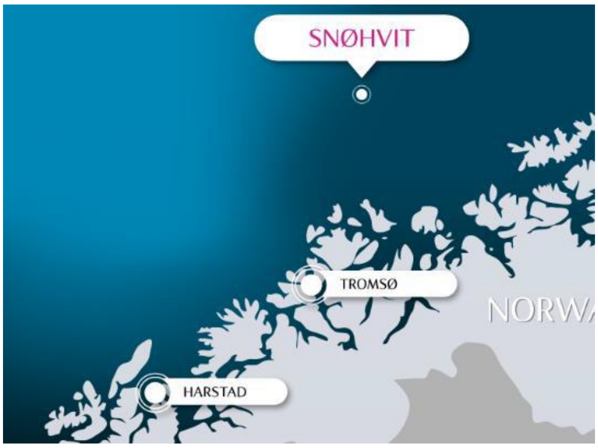


Figure 88:Location of Snøhvit on the map of Norway

The Snøhvit gasfield consists of 3 separate fields: Snøhvit, Albatross and Askeladd. The gas is extracted using 8 production wells operated by Statoil on behalf of 6 gas companies (Statoil (33%), Petoro (30%), TotalFinaElf (18.4%), Gaz de France (12%), Amerada Hess (3.26%) and RWE Dea (2.81%). By building the well, the gas rises to the surface due to its natural tendency to fill areas with the lowest pressure. Next the gas is transported by pipelines to Melkoya, in addition there is one umbical, two chemical pipelines and a CO2 pipeline.

During the construction of this plant the focus was particularly on the ecological impact. There are no mobile drilling barges or platforms because everything happens on the seabed. The parts are specifically designed to form no obstacle for fishing. A model of the production well is shown in Figure 89: Model of the production well in Snøhvit. In total the Snøhvit gas field extracts around 4% of the total world production while being the most environmental friendly liquefaction plant in the world.

Figure 89: Model of the production well in Snøhvit

Purification

After the natural gas is transported from the ocean to land, the natural gas needs to be purified. The natural gas is containing some non-hydrocarbons, like hydrogen sulphide, nitrogen, carbon dioxide and water. These compounds needs to be removed before the liquefaction will occur, because otherwise residue will build-up. Firstly a solvent is used to remove carbon dioxide, hydrogen sulphide and water. The heavier liquids are removed to be used for separated processing. The last step is to remove the last water in the gas. The pure natural gas is transported to the liquefaction plant.
In industry the purification is done by different equipment, but the m shown in Figure 90: Example of natural gas purification equipment

Figure 90: Example of natural gas purification equipment

Liquefaction

Figure 91: Cryogenic heat exchanger tower used for liquefaction of natural gas

In the liquefaction step, the natural gas will be cooled to -164°C to transform the gas into a liquid. By liquefying the volume will be decreased 600 times. The decrease in volume is the big advantage of transporting LNG over transporting natural gas. The most used heat exchanger for the liquefaction is the cryogenic heat exchanger tower. This heat exchanger is shown in Figure 91: Cryogenic heat exchanger tower used for liquefaction of natural gas. It is also possible to use different kind of refrigerants as explained in the Mixed Fluid Cascade definition. The cryogenic heat exchanger is using two different cooling circuits with two different refrigerants. Figure 92 Cross section of a cryogenic heat exchanger shows that there are two inputs with refrigerant, one at the top and one on the side. The refrigerant which is entering the heat exchanger from the top is distributed through the atmosphere in the heat exchanger. This refrigerant is flowing over the pipelines filled with natural gas. The second refrigerant is entering the heat exchanger at the same level as the feed and is in flowing in a pipeline around the natural gas pipeline. The temperature of the second refrigerant should be lower than the first one, because the second one is cooling the natural gas down at the end of the cooling down process (Coyle & Patel, 2016).

After liquefaction the liquid natural gas will be stored in storage tanks. Storing happens until the liquid natural gas can be loaded on a ship.

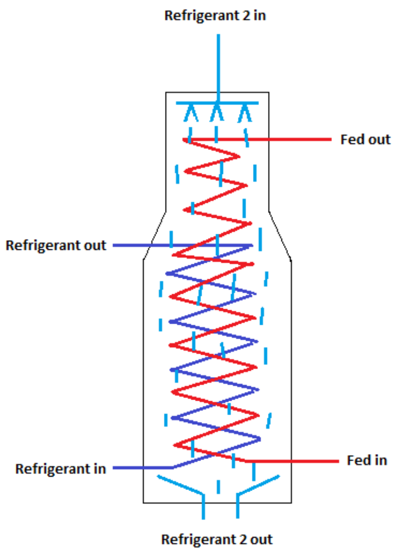


Figure 92 Cross section of a cryogenic heat exchanger

Storage

The gas is stored in the tanks, which keeps the gas at -164 °C. The tanks at the liquefaction plant and the terminal are the same. An LNG import terminal designer is faced with two important storage-related decisions: how many tanks to build and the type of storage tank required. Given that the LNG import terminal is often the only or main source of gas in a region, it is essential for its proponents to ensure the facilities are able to manage with unexpected surprises, like a delay in a freight delivery. The selection of a reservoir design and the associated foundation design will be influenced by several factors, in particular the geology, topography and soil conditions of the site, in particular with regard to vaporize dispersion and exclusion zone requirements and of course aesthetic considerations. Examples of storage tanks are shown in Figure 93 Example of LNG storage tanks. (Falco, 2015).

Figure 93 Example of LNG storage tanks

Shipping

The LNG transportation is easiest by ship. A LNG ship is containing three to four storage tanks on board. Those tanks need to be prepared before the loading of LNG can take place. Firstly, the tanks will be filled with an inert gas, which is reducing the risk of explosion. Secondly, the tanks are cooled-down. The cooling-down process is done by spraying LNG into the tanks, which by vaporising cools down the environment inside the tank. After the tanks are cooled, the LNG is pumped from the on-site storage tanks into the vessel tanks. This can be seen in Figure 94: example of a LNG transportation ship.

Figure 94: example of a LNG

Boil-off-gas

When heat increases in the equipment or facilities containing LNG, partial evaporation of the LNG is happening. The gas appearing is called the boil-off gas (BOG). If the BOG is not evacuated, the pressure increases in the tanks. To prevent this, compressors are used which maintain a stable pressure in the storage tanks. The BOG is evacuated to units of reincorporation where it is mixed with the emitted LNG.

Terminal installations require good insulators, especially liquid reservoirs and ducts, because LNG is a cryogenic liquid. A boiling of 0.05% per day of the reservoir volume is observed. Terminals are equipped with or a system which is capturing the BOG or a system to compress the gas and export it. The boil-off rates are higher when unloading the LNG tanker, because of the energy transferred by the pumping process. Part of the excess vapours are returned to the LNG carrier to maintain pressures in the vessels. If the terminal is owning its own gas-fired power generator, the residual gas can be used to generate the power needed for the plant. A remote flare stock is available to dispose the BOG when there is an equipment failure or when the BOG rate is exceeding the capacity of the recovery system (Tusiani & Shearer, 2007).

Regasification

The regasification process is the process were the LNG is transferred into gas again. This process can be done by different heat exchangers or vaporisers. The most applied regasification technologies are: open rack vaporiser, submerged combustion vaporizers and cryogenic heat exchangers.

This model uses an open rack vaporiser (ORV): Liquid LNG is located inside panels and sea water is running down in the opposite direction on the outside of the hollow panels. By this action, the LNG in the panels is heated by the flow of sea water. To prevent fouling of vaporisers by marine growth. Seawater and vaporisation systems must be treated with chemicals. These have an impact on the ocean environment, as the treated seawater is discharged into the ocean. The discharge of cold water into the sea also poses environmental problems, the fluctuation of water temperature has a negative impact on marine flora and fauna. To reduce this impact, sea water is heated with an intermediate fluid before being discharged into the ocean (Tusiani & Shearer, 2007).

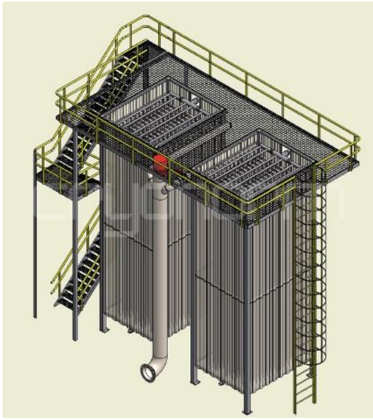


Figure 95 Example of an open rack vaporiser

End-users

Before leaving the terminal, the regasified LNG passes through a pressure-regulating and metering station to measure the gas. The gas may be odorized to aid in the detection of any leaks in the gas transportation system or customer appliances.

After the metering station the gas is ready to be sent to the different end-users. The end-users could be households, public transportation busses or the industry. For transportation to the end-users is it possible to use the piping system for natural gas (Falco, 2015).

LCD screen text

Because not all information can fit on the screens the most important one of each step is given. The teacher should know what button displays what text in order to explain the step thoroughly with the information given in the previous chapter.

Table 7: LCD screen text

Button	Text
Production well	The natural gas is extracted from the earth by the pumps. The main component of the natural gas is methane. Location: Snøhvit, Norway

CO_2 well	The CO_2 removed from natural gas is pumped back into the earth.
Purification process	The CO_2, H_2O and H_2S in the natural gas are impurities, which need to be removed. The impurities will be removed by the purification tanks.
Heat exchangers	The natural gas is cooled to -162°C by a heat exchanger, that is cryogenic and has two refrigerant circuits. By cooling the natural gas is turned into a liquid.
Refrigerant compressor	The compressor is used to stabilise the temperature and the pressure of the refrigerant.
Storage tanks	The LNG is stored before shipping. The flat-bottom tanks are isolated to ensure the temperature inside the tank.
Liquefaction terminal	The LNG is pumped into the LNG tanker. The LNG can be shipped
LNG tanker	The LNG is shipped with a LNG tanker. The spherical tanks are isolated to stabilise the temperature. The temperature can increase which results in boil-off-gas.
Regasification terminal	The LNG is received in the terminal.
Storage tank	The LNG is stored after shipping in the same kind of tanks as before shipping. During storage, Boil-off-gas can be formed due to increase in temperature.
Chimney	The chimney is used to burn the unwanted boil-off-gas. This is not preferable, because it will send greenhouse gasses in the atmosphere.
Boil-off compressor	Preferably, the boil-off-gas will be used in a powerplant. Before this is possible the gas will be compressed in the compressor.
Open rack vaporiser	An open-rack-vaporiser is a heat exchanger which is using seawater to heat up the LNG to make the LNG gaseous.
Metering station	In the metering station the quality and quantity of the natural gas is measured. From the metering station the natural gas is sent to the users.
Industry	Industry is one of the users of natural gas
LNG buses	Special buses can use NG as fuel instead of traditional fuels.
Households	Households can use the natural gas to heat their houses and to use as a cooking fuel.

Powerplant	The boil-off-gas will be converted in to power by the powerplant. This power can be used in the LNG process.

LNG transportation example test

This questionnaire will test the students understanding of the LNG miniature model. Answers should be given after the demonstration of the model.

1. What is the first physical transformation the natural gas is going through in the process?

A Liquefaction: going from gas phase to liquid phase
B Regasification: going from liquid phase to gas phase
C Melting: going from solid phase to liquid phase

2. When is the LNG stored?

A Before shipping the LNG
B Before liquefaction
C After shipping the LNG
D During purification
E Answers A and B are correct
F Answers A and C are correct
G Answers A, B, C and D are correct
H Answers B and C are correct

3. What are the three main users of natural gas?

A Households
B Farms
C Busses
D Electrical bikes
E Harbours
F Industry
G Construction companies

4. What is the typical shape of the storage vessels on the ship?

A Cylinderical
B Pyramidal
C Spherical

5. What is the advantage of Liquid Natural Gas over Natural Gas?

A The LNG is more flammable than the natural gas
B The liquid natural gas is having a lower volume
C The conduction of LNG is higher than of Natural Gas
D Less energy is required for the production
E There is no advantage

6. Which process step is essential before liquefaction?

A Distillation
B Pasteurisation
C Purification
D Sterilisation
E Emulsification

7. What is the main component of natural gas?
A Butane
B Propane
C Carbohydrates (length C12-C16)
D Methane
E Carbohydrates (length C4-C12)
F Carbon dioxide

8. What three components are removed during the purification step?
A Iron - Mercury - Sodium
B Carbon dioxide - Water - Hydrogen sulphide
C Hydrogen gas - Bacteria - Methane
D Chlorine - Bromide - Fluoride

9. In which process step is Boil-off-gas formed? (more answers can be correct)
A Storage
B Regasification
C Production
D Shipping

10. What is the purpose of the chimney?
A Evaporating the cooling water
B Burning off the unwanted boil-off-gas
C Investigating the energy density of the natural gas
D Burning off the refrigerant used in liquefaction
E Producing energy used in the regasification

Answers

1) **A**
2) **F**
3) **A,C,F**
4) **C**
5) **B**
6) **C**
7) **D**
8) **B**
9) **A,D**
10) **B**

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Appendix G

Schedule for the EPS project		Arno Van Dyck		
Date	starting time	Ending time	Hours	Description
2/02/2017	9:00	16:00	7:00	orientation day
3/02/2017	9:00	18:00	9:00	project summary and ice swimming
6/02/2017	8:30	17:30	9:00:00	Management Course + survival swedish
7/02/2017	8:30	15:00	6:30:00	Management Course + Making a schedule
8/02/2017	8:30	14:30	6:00:00	management course + Meeting with supervisor and researching
9/02/2017	12:30	16:00	3:30:00	Gantt chart
10/02/2017	10:00	16:00	6:00:00	sketching
11/02/2017	Weekend			
12/02/2017	Weekend			
13/02/2017	9:30	18:00	8:30	Sketching + Teambuilding + swedish
14/02/2017	9:30	16:15	6:45	English, teambuilding, belbin test, MS project
15/02/2017	Lapland		8:00	
16/02/2017	Lapland		8:00	
17/02/2017	Lapland		8:00	
18/02/2017	Lapland		8:00	
19/02/2017	Lapland		8:00	
20/02/2017	11:30	18:00	6:30	sketching + swedish + Gant
21/02/2017	9:30	14:00	4:30	Sketching + text about production + meeting
22/02/2017	9:30	15:20	5:50	Risk analysis + dismanteling old model
23/02/2017	9:30	16:45	7:15	English class + dismanteling old model
24/02/2017	9:30	15:00	5:30	Brainstorm about model implications
25/02/2017				
26/02/2017				
27/02/2017	9:30	17:00	7:30	Designing storage tanks
28/02/2017	9:30	16:30	7:00	Designing production well
1/03/2017	9:00	16:00	7:00	Designing LNG tanker
2/03/2017	9:00	15:00	6:00	Designing heat exchanger

3/03/2017	10:00	16:00	6:00	Designing heat exchanger
4/03/2017				
5/03/2017				
6/03/2017	10:00	18:00	8:00	CSR course, Survival swedish, english presentation preparation
7/03/2017	10:00	16:00	6:00	CSR course, Meeting with 3D printing lab, updating models for printing standards
8/03/2017	10:00	16:00	6:00	3D printing tutorial by Ossku, printing first model, english class
9/03/2017	8:00	16:00	8:00	Wartsilla visit + designing bullet tanks
10/03/2017	9:30	16:00	6:30	Starting with the vaporiser design
11/03/2017				
12/03/2017				
13/03/2017	9:00	17:30	8:30	finishing design OVR + printing OVR + swedish
14/03/2017	8:00	16:30	8:30	Designed a new exchanger + meeting + overview design + woodwork for the board
15/03/2017	10:00	16:30	6:30	Modeling house + factory + printing compressor
16/03/2017	10:00	16:30	6:30	Slicing models
17/03/2017	9:30	16:15	6:45	Paint store + finishing all models
18/03/2017				
19/03/2017				
20/03/2017	9:30	17:45	8:15	printing callibration + boat + swedish
21/03/2017	10:00	16:15	6:15	helping with Electrical work
22/03/2017	11:30	15:30	4:00	Notes about the models
23/03/2017	9:30	15:30	6:00	Notes about the models + giving presentation for energy week
24/03/2017	9:30	13:00	3:30	Finishing text about different models
25/03/2017	Baltic Pirates			
26/03/2017	Baltic Pirates			
27/03/2017	Baltic Pirates			
28/03/2017	Baltic Pirates			

29/03/2017		8:45	17:00	8:15	meeting + CSR course + report work
30/03/2017		8:30	18:00	9:30	Making powerpoint presentation + report work
31/03/2017		8:30	13:00	4:30	rehearsel of powerpoint
1/04/2017					
2/04/2017					
3/04/2017		8:00	17:45	9:45	presentation + swedish
4/04/2017		9:30	16:00	6:30	soldering LED
5/04/2017		8:00	16:00	8:00	CSR course work
6/04/2017		9:00	16:00	7:00	remoddeling last models + soldering LED
7/04/2017		12:00	16:00	4:00	Working on CSR report
8/04/2017					
9/04/2017					
10/04/2017		13:00	18:00	5:00	soldering last leds + swedish
11/04/2017	St. Petersburg				
12/04/2017	St. Petersburg				
13/04/2017	St. Petersburg				
14/04/2017	St. Petersburg				
15/04/2017	St. Petersburg				
16/04/2017	St. Petersburg				
17/04/2017	St. Petersburg				
18/04/2017		9:00	17:00	10:00	Working out electrical work, refining printing +2h of CSR course work 19:00 - 22:00
19/04/2017		8:00	17:00	11:00	Installing the buttons + leds --> testing + 2h of english assignments
20/04/2017		9:00	16:30	9:30	Installing the button board on the frame + model board + 2h of swedish voc
21/04/2017		9:30	16:00	6:30	Glueing the wires together + fixing some details
22/04/2017		12:00	16:00	4:00	Learning for swedish
23/04/2017		11:00	16:00	5:00	Learning for swedish + CSR diary
24/04/2017		10:00	17:00	7:00	Rehearsel of swedish + remoddeling powerplant + swedish exam

25/04/2017	10:00	16:00	6:00	Printing last model + starting with teachers' manual
26/04/2017	11:00	18:00	7:00	helping W33 group with printing + finishing teacher's manual
27/04/2017	10:00	18:00	8:00	helping W33 group with printing + finishing teacher's manual
28/04/2017				
29/04/2017				
30/04/2017				
1/05/2017	15:00	16:00	1:00	writing the risk management + picture folder
2/05/2017	10:00	16:00	6:00	Assisting making holes in wooden plate + Repainting board
3/05/2017	10:00	17:30	7:30	Assemblying pipelines
4/05/2017	10:00	16:30	6:30	Assemblying pipelines
5/05/2017	9:00	15:30	6:30	report writing
6/05/2017				
7/05/2017				
8/05/2017	10:00	16:30	6:30	Report writing + printing LCD case + meeting
9/05/2017	9:00	16:00	7:00	writing report + fixing last model issues
10/05/2017	9:00	19:00	10:00	final touches on the model + testing
11/05/2017	9:00	16:00	7:00	report writing
Total			459:05:00	

Schedule for the EPS project		Carineke Post		
Date	starting time	Ending time	hours	Description
2/02/2017	9:00	16:00	07:00:00	orientation day
3/02/2017	9:00	18:00	09:00:00	project summary and ice swimming
6/02/2017	8:30	17:30	09:00:00	Management Course + survival swedish
7/02/2017	8:30	14:30	06:00:00	Management Course + Research
8/02/2017	8:30	15:15	06:45:00	Management course + Meeting with supervisor and researching + attanding speech
9/02/2017	8:30	16:00	07:30:00	Management Course + Watching different youtube video's about liquification process + Gantt chart + reading article Wartsila
10/02/2017	10:00	18:00	08:00:00	Reading article Linde + Make 2D sketch + writing overview liquafaction + starting with 3D sketch
11/02/2017	Weekend			
12/02/2017	Weekend			
13/02/2017	10:00	18:00	08:00:00	Team building + Swedish + Belbin test
14/02/2017	9:30	16:00	06:30:00	Discussing Belbin test + Team building
15/02/2017	Lapland		08:00:00	
16/02/2017	Lapland		08:00:00	
17/02/2017	Lapland		08:00:00	
18/02/2017	Lapland		08:00:00	
19/02/2017	Lapland		08:00:00	
20/02/2017	11:30	18:00	06:30:00	Swedish + Discussing Project managment + Finishing theory part purifaction and liquafaction + Searching for pictures of equipment
21/02/2017	9:30	16:00	06:30:00	Searching for pictures of equipment + Project meeting + Putting theory part together
22/02/2017	9:30	16:10	06:40:00	Almost finishing theory part (only regasification needs to be done), dismantling old model
23/02/2017	9:30	16:45	07:15:00	English class + dismanteling old model
24/02/2017	9:30	16:00	06:30:00	Brainstorm about model implications + Starting writing introduction
25/02/2017	Weekend			

26/02/2017	Weekend			
27/02/2017	9:30	17:00	07:30:00	Designing purification model
28/02/2017	9:30	16:30	07:00:00	Trying to design the heat exchange
1/03/2017	9:30	16:45	07:15:00	Elaborate the project management part
2/03/2017	9:10	16:00	06:50:00	Making template for midterm report + Preparing presentation for English course
3/03/2017	Weekend			
4/03/2017	Weekend			
5/03/2017	Weekend			
6/03/2017	9:30	17:45	08:15:00	CSR - Studying for Swedish - Swedish
7/03/2017	10:00	16:00	06:00:00	CSR - Project meeting - Putting mid-term report together - implementing feedback Roger
8/03/2017	8:00	17:15	09:15:00	CSR - Preparing English presentation - English class - Working on project management part - 3D printing
9/03/2017	8:00	16:15	08:15:00	Visit Wartsila + Process Flow Diagram LNG chain
10/03/2017	9:30	16:00	06:30:00	Working on Midterm report (theory part)
11/03/2017	Weekend			
12/03/2017	Weekend			
13/03/2017	10:00	17:30	07:30:00	CSR + Working on Midterm report + PFD + Swedish
14/03/2017	8:00	16:30	08:30:00	CSR + Working on Midterm report + meeting
15/03/2017	9:45	17:15	07:30:00	Finished first part Midterm report + supporting 3D printing
16/03/2017	10:00	16:30	06:30:00	Added part on natural gas in Finland to the midterm report + started with the 3D sketch part
17/03/2017	9:30	16:15	06:45:00	Paint store + working on the midterm report
18/03/2017	Weekend			
19/03/2017	Weekend			
20/03/2017	9:45	17:45	08:00:00	Dismanteling the old miniature model + added ground layer to the board
21/03/2017	10:00	16:15	06:15:00	Painting the sea on the board + Writing introduction

22/03/2017		10:30	17:45	07:15:00	Finishing the introduction on the midterm report + painting the land + started with the future plan part
23/03/2017		10:00	17:15	07:15:00	Almost finished the future plan part + painting second layer land
24/03/2017		9:30	18:30	09:00:00	Working on CSR assignment + Painting the second layer sea + assisting 3D printing
25/03/2017		15:00	18:30	03:30:00	Finishing CSR report + Preparing CSR presentation
26/03/2017	Weekend				
27/03/2017	Weekend				
28/03/2017		20:00	21:00	01:00:00	Preparing CSR presentation
29/03/2017		8:30	17:30	09:00:00	CSR + Meeting + PFD + Survey/Test + English
30/03/2017		8:30	19:00	10:30:00	English + writing discussion + Putting in references + Improving references
31/03/2017		9:00	17:00	08:00:00	Finishing report + Practising presentation
1/04/2017	weekend				
2/04/2017		19:00	19:30	00:30:00	Practising presentation
3/04/2017		8:00	17:45	9:45	Presentation day + Swedish
4/04/2017		9:30	16:00	6:30	English + Meeting + putting models in place + soldering
5/04/2017		9:30	16:00	6:30	English + Measuring button board
6/04/2017		9:30	16:30	7:00	Designing sticker for button board + Designing logo
7/04/2017		9:30	16:00	6:30	Printing terminals + English + writting tekst LCD screens
8/04/2017		Weekend			
9/04/2017		Weekend			
10/04/2017		9:30	17:45	8:15	Studying Swedish + Meeting with Arno + Swedish class
11/04/2017		9:30	16:30	7:00	English assignment + improving sticker
12/04/2017		9:30	17:00	7:30	English assignment + CSR learning diary
13/04/2017		Easter Holiday			
14/04/2017		Easter Holiday			
15/04/2017		Easter Holiday			
16/04/2017		Easter Holiday			
17/04/2017		Easter Holiday			

18/04/2017	8:45	17:00	8:15	Meeting + Working on web page
19/04/2017	8:00	17:00	9:00	CSR + Learning Swedish + Fixing sticker for button board + Assisting fixing button board + Working on webpage
20/04/2017	9:15	17:00	7:45	Finished webpage (what was possible) + finished LCD tekst + preparing meeting + studying Swedish
21/04/2017	9:00	16:30	7:30	Studying Swedish + Weekly meeting + Working on template for final
22/04/2017	Weekend			
23/04/2017	Weekend			
24/04/2017	9:00	16:30	7:30	Studying for Swedish test + Swedish test
25/04/2017	9:30	16:00	6:30	Preparing to do list final report + small meeting with team + writing description of the logo
26/04/2017	9:30	17:15	7:45	Writing management summary for final report + changing template final report
27/04/2017	10:00	17:00	7:00	Writing description of website + Adding midterm tekst to final report
28/04/2017	9:30	16:30	7:00	Writing description design sticker + Adding midterm tekst to final report
29/04/2017	15:00	20:00	5:00	Making English assignment + CSR learning diary
30/04/2017	13:00	18:00	5:00	CSR learning diary
1/05/2017	10:00	15:00	5:00	Writing introduction + Writing infromation on the socrative test
2/05/2017	10:00	16:00	6:00	Assisting making holes in wooden plate + Repainting board
3/05/2017	10:00	17:30	7:30	Assemblying pipelines
4/05/2017	10:00	16:30	6:30	Assemblying pipelines, searching for measurments
5/05/2017	9:30	16:00	6:30	Working on EPS movie
6/05/2017	Weekend			
7/05/2017	Weekend			
8/05/2017	9:15	17:30	8:15	Working on EPS movie and meeting
9/05/2017	9:30	16:00	6:30	EPS movie + correcting report
10/05/2017	9:15	15:15	6:00	Testing model + writing parts report
11/05/2017	9:00	19:00	10:00	Writing about test results + Checking report + Adding appendices
12/05/2017				

13/05/2017	Weekend	
14/05/2017	Weekend	
Total		514:30:00

Schedule for the EPS project		Bétina Salmon		
Date	starting time	Ending time	hours	Description
2/02/2017	9:00	16:00	6:00:00	orientation day
3/02/2017	9:00	12:00	2:00:00	project summary and ice swimming
6/02/2017	8:30	17:30	8:00:00	Management Course + survival swedish
7/02/2017	8:30	15:30	6:00:00	Management Course + Research
8/02/2017	9:00	15:00	5:00:00	management course + Meeting with supervisor and researching
9/02/2017	12:30	16:00	2:30:00	research of transport and regasefication
10/02/2017	10:00	16:00	5:00:00	research procesus and picture with the best explications regasefication and transport
11/02/2017	Weekend		0:00:00	
12/02/2017	Weekend		0:00:00	
13/02/2017	9:30	12:00	1:30:00	Teambuilding + swedish course + research of regasefication
14/02/2017	9:30	16:15	5:45:00	English course + teambuilding + belbin test
15/02/2017	10:00	16:00	5:00:00	Belbin Test
16/02/2017	8:00	17:00	8:00:00	Gant + draw 3D model + english course
17/02/2017	9:00	15:00	5:00:00	write and make a plant
18/02/2017	Weekend		0:00:00	
19/02/2017	Weekend		0:00:00	
20/02/2017	11:00	12:00	0:00:00	cswedish course + Project proffesionnel
21/02/2017	9:00	14:00	4:00:00	part "Constraint and initial situation" of the report
22/02/2017	9:30	16:10	5:40:00	report

23/02/2017		11:00	16:45	4:45:00	English class + report
24/02/2017		9:30	16:00	5:30:00	research of picture regasefication
25/02/2017	Weekend			0:00:00	
26/02/2017	Weekend			0:00:00	
27/02/2017		9:00	15:00	5:00:00	report terminal, research picture of proces + Part electrical
28/02/2017		8:30	16:00	6:30:00	part electrical, research informations
1/03/2017		8:30	17:00	7:30:00	Brainstorm + Part electrical
2/03/2017		9:00	15:00	5:00:00	Brainstorm + research material do you need of Arduino
3/03/2017		10:00	16:00	5:00:00	Research of Arduino
4/03/2017	Weekend			0:00:00	
5/03/2017	Weekend			0:00:00	
6/03/2017		8:30	12:00	2:30:00	CSR + swedish course + electrical report
7/03/2017		8:30	16:00	6:30:00	CSR
8/03/2017		8:00	15:00	6:00:00	CSR - Preparing English presentation - English class
9/03/2017		8:00	16:00	7:00:00	Visit Wartsila + Process Flow Diagram LNG chain
10/03/2017		9:30	16:00	5:30:00	electrcial
11/03/2017	Weekend			0:00:00	
12/03/2017	Weekend			0:00:00	
13/03/2017		8:30	17:30	8:00:00	CSR + electrical + Swedish
14/03/2017		9:00	16:30	6:30:00	CSR + electrical + meeting
15/03/2017		9:00	12:00	2:00:00	part electrical
16/03/2017		9:00	15:00	5:00:00	part regasification for the midterm report
17/03/2017		9:00	15:00	5:00:00	Purchase of paint supplies
18/03/2017	Weekend			0:00:00	
19/03/2017	Weekend			0:00:00	
20/03/2017		9:00	17:00	8:00:00	Dismanteling the old miniature model + Part electrical
21/03/2017		8:30	16:00	7:30:00	Part electrical + solder
22/03/2017		8:30	15:00	6:30:00	Electrical part + make a test
23/03/2017		8:30	16:00	7:30:00	Electrical part + oder Arduino
24/03/2017		8:30	12:00	3:30:00	CSR + electrical part
25/03/2017		8:30	16:00	7:30:00	Electrical part
26/03/2017	Weekend			0:00:00	
27/03/2017		0:00	0:00	0:00:00	

28/03/2017		8:30	15:00	6:30:00	CSR + Meeting + English
29/03/2017		8:30	14:00	5:30:00	English + electrical part report
30/03/2017		8:30	15:00	6:30:00	electrical part report
		8:00	17:45	9:45:00	Presentation day + Swedish
4/04/2017	Holiday				
5/04/2017	Holiday				
6/04/2017	Holiday				
7/04/2017	Holiday				
8/04/2017	Holiday			0:00:00	
9/04/2017	Holiday			0:00:00	
10/04/2017	Holiday				
11/04/2017	Holiday				
12/04/2017	Holiday				
13/04/2017		Easter Holiday			
14/04/2017		Easter Holiday			
15/04/2017		Easter Holiday		0:00:00	
16/04/2017		Easter Holiday		0:00:00	
17/04/2017		Easter Holiday			
18/04/2017		8:45	17:00	8:15:00	Meeting
19/04/2017		8:00	17:00	9:00:00	Installing the buttons + leds
20/04/2017		9:15	17:00	7:45:00	Installing the button board on the frame + model board
21/04/2017		9:00	16:30	7:30:00	Studying Swedish + Weekly meeting + Working on template for final
22/04/2017		Weekend		0:00:00	
23/04/2017		Weekend		0:00:00	
24/04/2017		9:00	16:30	7:30:00	test with the led with the screen
25/04/2017		9:30	16:00	6:30:00	add screen step to step
26/04/2017		9:30	17:15	7:45:00	solder every connexion on each screen with wires
27/04/2017		10:00	17:00	7:00:00	add screen on the model
28/04/2017		9:30	16:30	7:00:00	make every connexions
29/04/2017	Weekend			0:00:00	
30/04/2017	Weekend			0:00:00	
1/05/2017		10:00	15:00	5:00:00	solder connexions

2/05/2017		10:00	16:00	6:00:00	test screens
3/05/2017		10:00	17:30	7:30:00	implemented text sentence on the screen
4/05/2017		10:00	16:30	6:30:00	code arduino
5/05/2017		9:30	16:00	6:30:00	code arduino
6/05/2017	Weekend			0:00:00	
7/05/2017	Weekend			0:00:00	
8/05/2017		9:15	17:30	1:00:00	code arduino
9/05/2017		9:30	16:00	2:00:00	part electrical
10/05/2017		9:00	15:00	3:00:00	writing in the repport
11/05/2017		9:00	16:00	4:00:00	Finish the details model
12/05/2017		10:00		5:00:00	Finish the project
13/05/2017	Weekend			6:00:00	
14/05/2017	Weekend			7:00:00	
15/05/2017					
16/05/2017					
17/05/2017					
18/05/2017					
19/05/2017					

total 359:10:00