EPS Autumn 2017

Final Report

Wet Grain Packaging

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I. Abstract

The agricultural area in the Nordic area is composed of big agricultural exploitations but also small local farms, which in most of the cases, do not have the necessary production for using silos. Under these circumstances, small, local farms are using big plastic tubes for the storage of the wet grain. The biggest problem of this type of packaging is the afterlife of the technology, as nowadays the plastic tubes cannot be recycled after their use. The big tubes are just burned or thrown into a landfill, which is the worst solution in terms of waste management.

Hans Arvidsson introduced the project 'Wet Grain in Package' at the beginning of the year 2017. The aim of this project can be summarized as the investigation of handling the plastic waste which arises from the packaging process of wet grain. In other terms, the 'Wet grain in package' team must find the best type of plastic for the new package method which must have a commercial value after it's usage.

The project is conducted by the EPS, short for 'European Project Semester'. The program aims to create international and usually interdisciplinary teams of 3-6 students on their projects. It is mainly focused on engineering students, but also students from other study fields can join the program. For students, the program is an opportunity to improve their communication skills and their intercultural competencies.

The report starts with the project backgrounds which include the introduction of the EPS, the group members and the project 'Wet Grain in Package' with the mission and vision of the team. Project management is a way to get more structure within the team. This structure gives the team a better overview of what must be done during the project.

Research will be done in the project execution. During the project execution the team clarifies the possible solutions to handle the plastic waste which arise from the packaging. The research will introduce a new way of packaging, a solution to reduce the plastic waste and the research of commercial value after the use of the packaging. A side topic of this project is the research of edible packaging, clearing the questions how far the development of this technology is and if it could be introduced in the agricultural sector as a packaging.

The new type of packaging exists out of two separated bags, the outer bag is made of Polypropylene and the inner bag is made of Polyethylene. To get a commercial value out of the downcycle process, the material will be cleaned and extrude into a secondary product. The polypropylene waste will be downcycled in a plastic stool, polyethylene waste will be downcycled into garbage bags. The edible packaging is not developed enough to apply the type of packaging in the agricultural sector. A further research should concentrate more on the characteristics of the material, so that it can be applied in the agricultural sector as an inner bag. The case study at the end shows that the new type of packaging will not only reduce the plastic waste after a certain thickness of the inner bag it is able to reduce the agricultural waste. With the new way of packaging the farmers can trade bags with each other, there are several strategies written to show the possibilities for the trading system and collecting the plastic waste.

II. Table of Content

1 Project Backgrounds

1.1 European Project Semester (EPS)

The European Project Semester is a program offered by 18 European universities in 12 countries throughout Europe to students who have completed at least two years of study. It is a program which is mainly focusing on engineering students, but also students from other study fields can join the program. It aims to create an international and multidisciplinary environment to prepare students for the working life in project teams and, thanks to this environment, improving the communication skills of the students and their intercultural competencies. It contains the project itself and several supporting courses, for example 'Teambuilding' and 'Project Management'. Students work in an international and usually interdisciplinary team of 3–6 students on their projects and write a Mid-Term Report and a Final Report about the project progress and outcome. At the end of the semester, a student will gain 30 ECTS which represent a normal academic semester.

On the official website of the European Project Semester, this graph of the fields that the program involves, can be found:

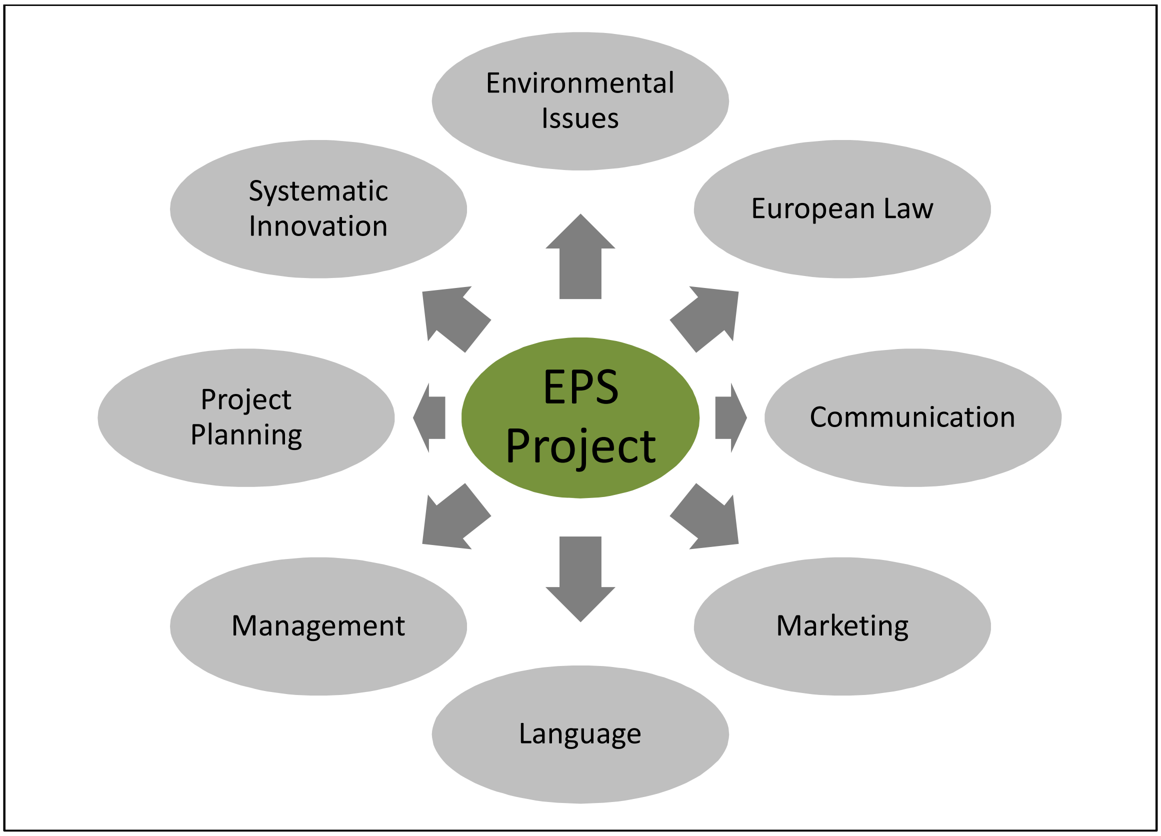


Figure 1: Topics of the EPS project (Novia, 2017)

1.2 Novia University of Applied Sciences

Situated in the city of Vaasa, on the Finnish west coast at the narrowest point of the Gulf of Bothnia, the Novia University of Applied Sciences is the largest Swedish-speaking university of applied sciences in Finland with over 4000 students and a staff of about 300 people. The following figures show the logos of the Project Semester and the university.

Figure 2: Logos of the Project Semester and the Novia University ©Novia University

The EPS projects at Novia UAS are projects given by external industrial customers or Research & Development departments and institutes. The tasks are often combined with renewable energy and durable development because of the Vaasa's region, which is the first provider of energy solutions, innovations and research in this field in Finland. The following table shows the other projects of the European Project Semester in Autumn 2017.

Table 1: List of projects in the European Project Semester – Autumn 2017

Project name	Team name	Team Logo	Project website
Circular Economy	The Circle		thecircleeps.wordpress.com
3D printing robotic arm	Probot		probotweb.wordpress.com
Automatic tomato picker	Robopick		robopick.wordpress.com

1.3 Transnational R&D-Project 'Wet Grain In Package'

This project is a sub-project of the transnational Research and Development program 'Wet Grain in Package'. According to the description on the website of the project region (www.botnia-atlantica.eu), the aim of the 'Wet Grain in Package' project is to increase the profitability of grain cultivation in the Botnia-Atlantica program area. The goal is that the team develops an energy saving, cost and environmentally effective system to pack, store and manage crimped grain at high water content in large plastic bags. The final purpose of the project is to increase the profitability of grain cultivation in the program area. To reach this goal, several infrastructures and actors are implied and have a specific role or task in the project development. The following figure shows the project region and the participants.

Figure 3: Map of the project region and location of the participating R&D institutes

The Swedish University of Agricultural Sciences and the Norwegian Institute of Bioeconomy Research conduct field studies and experiments on the grain to determine the optimal time for harvesting the grain in relation to the bag storage. The Swedish Machinery Institute is responsible for the construction of the new packaging machinery. It is a complete new development, because no producer of agricultural machines has a suitable product.

The Novia University of Applied Sciences works on various projects of the 'Wet Grain in Package' program. Within the Novia's team, there is Mikael Billing who is in charge to find a trading system for the development of the storage units. Niklas Frände and Yvonne Dahlback oversee the life cycle analysis of the bags and the EPS team takes care of the handling of the plastic waste that arises from the crimping process.

1.4 The team behind the sub-project 'Handling of the plastic waste'

The sub-project about the 'Handling of the plastic waste that arises from the packaging process of wet grain' was worked out by a group of students, who participated in the European Project Semester. This team had the name 'Korntainer'. The chapter offers some background information about the team members, their individual strengths and their mission and vision. Knowing the different personalities, studies and cultural backgrounds of each member may help to get a better understanding of the approach and the results of this report

1.4.1 Team members

The team is composed of four multidisciplinary and international members, representing three different nationalities: Dutch, German and French. For each of them, it was the first time working in such an international group. But this experience was very rewarding, and it allowed all members to widen their horizons. Indeed, all team members took responsibilities and participated in the project with their own cultural background, work habits and way of tackling a problem. This project was a good way to test the team spirit and degree of adaptability.

A short presentation of each member of the team is depicted below.

Hugo Bonnafous

Hello! I'm Hugo and I'm from Toulouse, France. I'm 21 and I'm in my third study year of Mechanical Engineering in National Engineering School of Tarbes. I made this EPS project to have the opportunity to work on a project in an international team, to improve my English skills and to discover a new culture. I like reading, hiking, discover new things and spend good time with friends.

Michael Haimerl

Hello, my name is Michael Haimerl. I am from Bad Tölz, a small town near Munich, Germany. I am 25 years old and I received my degree 'bachelor of engineering in wood technology' in November 2015. I was working as an engineer for one year and I began my master studies in 'Industrial Engineering' in October 2016. The European Project Semester is my final semester before my master thesis and I joined the program to improve my language skills and my cross-cultural knowledge. I like to do activities and to get to know new people. My favorite activities are hiking, biking and soccer.

Gijsbert Houtman

Hello, I am Gijsbert Houtman. I'm from Utrecht in the Netherlands. I am 19 years old and studying mechanical engineering at Avans university of applied sciences Den Bosch. I joined the European Project Semester for the possibility to work in a multicultural project group. Working with people in a group project requires good leadership and collaboration skills, I want to learn further to work together with people from different countries with different languages. I also want to expand my study experience abroad. I'm interested in Finland because of their experience and innovations with sustainable solutions, for example the project of the wet grain package.

Jasper van Dreumel

Hello, I'm Jasper and I'm from Nijmegen, The Netherlands. I'm 21 and I'm a third-year student of Mechanical Engineering at the Avans University of Applied Science in `s-Hertogenbosch. I followed the EPS project to collaborate in a project group with international students. I want to experience a new surrounding and get to know new people. I like football, watching sports, traveling and having good time with my friends.

1.4.2 Analysis of the Gallup StrengthsFinder profiles

At the beginning of the academical semester in September, every participant of the European Project Semester had to do an online test, which is called 'Gallup StrengthsFinder'. This test consists of various questions and prescribed answers and you need to decide whether one of the answers fits to your attitude or not. At the end, the test gives a report about the five main strengths of each test participant by a detailed description. The program 'Gallup StrengthsFinder' knows 34 strengths in total. These strengths can be classified by using four main areas, which are called 'Executing', 'Influencing', 'Relationship Building' and 'Strategic Thinking'. The following figure on the next page gives an overview of all strengths. Their meaning can be looked up in the appendix 1.

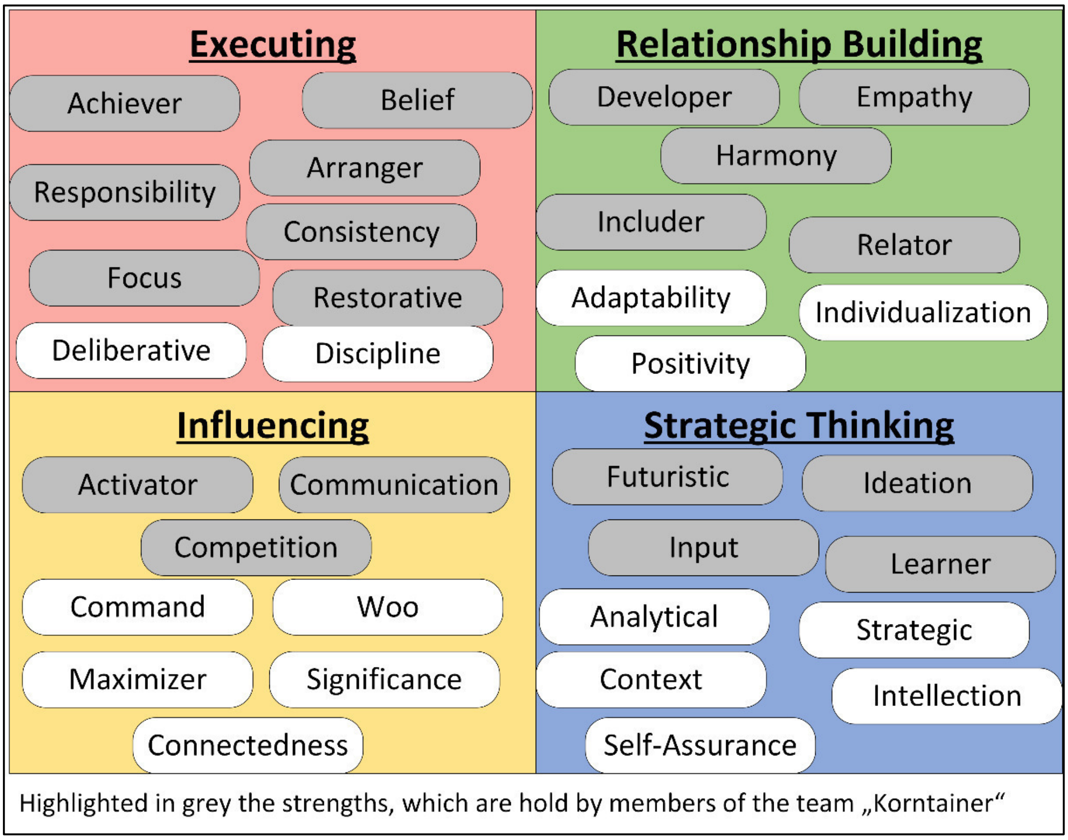


Figure 4: Overview of the 34 strengths of the Gallup StrengthsFinder

As it is shown in the figure above, the four members of the project team 'Korntainer' have 19 main strengths in total. Only the strength 'Ideation' is assigned to two members and this shows that the strengths profile of the whole team is as diverse as it could be. The meaning of this great diversity will be explained by the Table 2, which shows the team profile in detail.

Table 2: Strengths profile of the team in detail

Korntainer Wet Grain Package	Executing								Influencing				Relationship Building						Strategic Thinking				
	Achiever	Arranger	Belief	Consistency	Focus	Responsibility	Restorative	**Total Executing**	Activator	Communication	Competition	**Total Influencing**	Developer	Empathy	Harmony	Includer	Relator	**Total Relationship Building**	Futuristic	Ideation	Input	Learner	**Total Strategic Thinking**
Jasper van Dreumel		1		1				**2**				**0**		1	1	1		**3**					**0**
Gijsbert Houtman	1				1			**2**	1		1	**2**						**0**	1				**1**
Michael Haimerl			1			1		**2**		1		**1**	1					**1**		1			**1**
Hugo Bonnafous							1	**1**				**0**					1	**1**		1	1	1	**3**
In Total	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**7**	**1**	**1**	**1**	**3**	**1**	**1**	**1**	**1**	**1**	**5**	**1**	**2**	**1**	**1**	**5**

Every member of the team brings his unique main talent into the project. According to the explanations given by the Gallup reports and the coordinator of this StrengthsFinder workshop, Mr. Peter Menger, this means that the project group has good conditions to work effectively as a real team, because there is no potential for conflict. There are not two team mates with the same strong commanding nature for example, and that makes it easier and more effective to work together.

This was exactly the case during all the project. On the one side, we see Gijsbert, Jasper and Michael having strengths in the execution part, which were helpful in the research of information and the calculation for the case study. On the other side, we have Hugo and his strengths in strategic thinking, which helped the team to structure all the information without losing the focus on the given objectives. For this reason, his role as a secretary fitted perfectly to him. During all the semester the team was able to work together, in collaboration, without any problems. That is why the changing of the chairman and the secretary of the team in the middle of the project was not problematic and the work has never fallen behind the definite schedule.

But the team also faced some problems. There was a lack of the strengths ‘Discipline’, ‘Command’ and ‘Strategic’, the team struggled with the start phase of the project. Without any commands, discipline and strategic thinking, the team members dealt with many things, for example organizing of documents for the home university, but not with the project itself. Matters were made worse by the fact that, in addition to these start problems, the project customers did not take actions or measures. The project is a basic research and there are no definite borders or a framework. Because of this fact and the missing talent ‘Adaptability’, the group had difficulties to deal with this situation of no concrete objectives and without any given work structure.

At first, the team members tried to formulate own objectives and a framework for the project, but still there were no structure or an efficient work style in the elaboration of the project. Things changed after a skype conference with the Swedish expert Hans Arvidsson. He helped the team to develop a concrete framework for the project and emphasized the basic research character of this project, which allows creative thoughts and approaches. Since this conversation, the work of the team has been successful, because the team had clear objectives.

1.4.3 Analysis of the Belbin test profiles

After the analysis of the single strengths of each participant of the European Project Semester by using the Gallup StrengthsFinder method, the EPS coordinator Roger Nylund used a different method to examine the strengths of the members of each team. It is called the ‘Belbin Test’ and consists of questions to different scenarios, which describe the work in a new team. The participant should distribute ten points to the given answers by considering their importance for him or her. This test was accompanied by courses in Teambuilding to analyze the profiles of the members of each team more in detail.

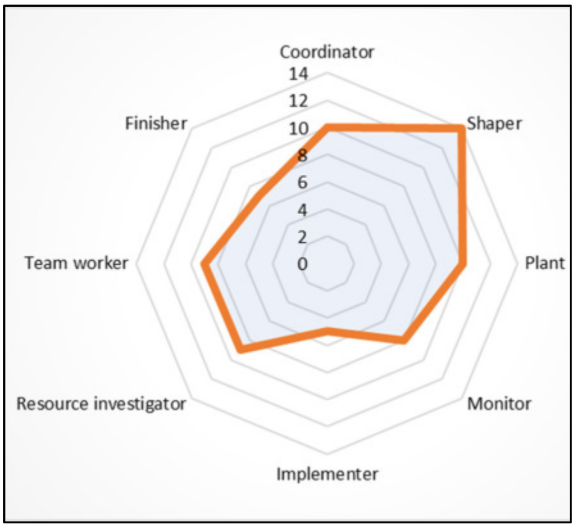
According to the author of the test, Meredith Belbin, a British management theorist, each member of a team tends to take a specific team role. A Team Role is defined as ‘a tendency to behave, contribute and interrelate with others in a particular way.’ (UK, 2015) This means, that having different personalities and ways of working in a group, makes it easier to accomplish a task and to manage the whole project. Mister Belbin distinguished eight team roles, which are shown in the following figures for each team member.

Gijsbert Houtman

Gijsbert has a strong Axe ‘Coordinator’/’Shaper’/’Plant’ in his Belbin profile.

Gijsbert Houtman

	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	1	2	2	2	0	1	2	0
2	2	3	2	2	0	0	1	2
3	2	1	1	2	0	2	1	1
4	1	1	2	0	1	1	2	2
5	1	2	1	1	1	2	1	1
6	1	2	1	1	1	1	2	1
7	2	3	1	0	2	2	0	0
Total	**10**	**14**	**10**	**8**	**5**	**9**	**9**	**7**
	think				act			



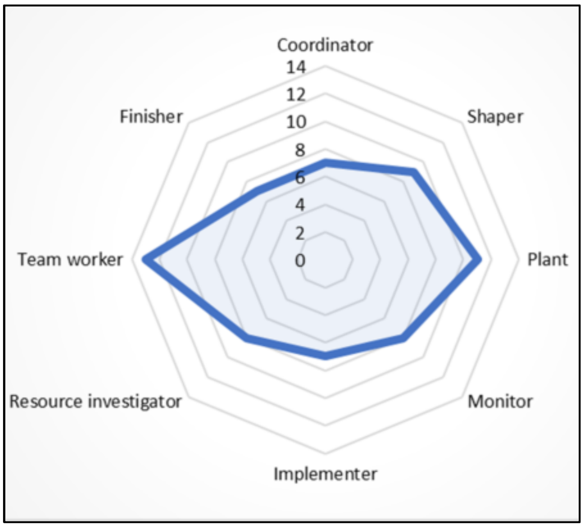
This is reflected by his investment of time and effort. Every time he started a task he was focused and worked on it until its end. At the same time, he was able to work individually on his part of the project, setting his own goals and milestones, while involving the other team members on his work to have their feedbacks. His 'plant' part allowed him to find the solutions for the problems he faced all along the project. Gijsbert was a good team member because he was not afraid to carry complex and long tasks. A good example for his working style is the case study. Seeking for every detail, he made it as precise as possible.

Hugo Bonnafous

The 'team worker' part of Hugo has been highlighted all along the project by his strong attitude to help his teammates on their work in every situation.

Hugo Bonnafous

	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	2	1	1	2	1	0	2	1
2	1	2	3	1	0	0	2	1
3	2	1	1	1	0	3	1	1
4	1	1	2	2	1	2	1	0
5	0	0	0	1	2	1	4	2
6	0	1	3	1	2	1	2	0
7	1	3	1	0	1	1	1	2
Total	**7**	**9**	**11**	**8**	**7**	**8**	**13**	**7**
	think				act			

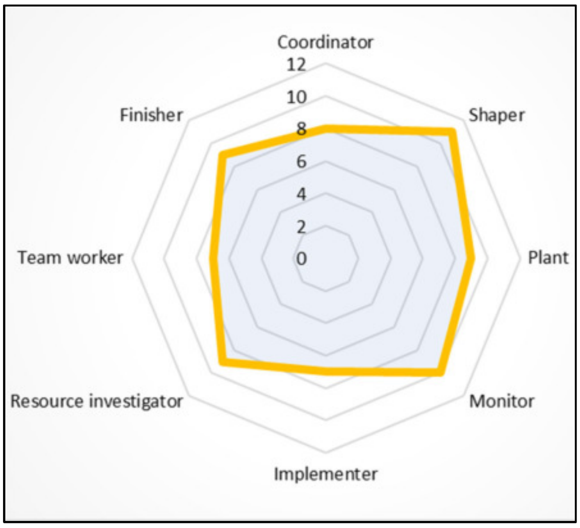


Whether it was on the review of parts of the written report or in the seeking of complementar informations, he has always tried to assist the others on their work. He also worked intensively on the sharing of information within the team and with other project participants, for example the tutors and the external companies. The 'shaper' and 'plant' part were shown by the fact that he was always active during a debate about project problems. He has always shared his ideas and his point of view. Hugo always worked in an useful way for the team.

Jasper van Dreumel

As the analysis of his Belbin profile would suggest, Jasper did a lot of things during the project. On the one side, he was able to do his own research and realized his part without any help. On the other side, he was always an active member during debates about the future direction of the project. He was also able to take the lead of the team, when it was necessary and gave instructions and tasks to the other members. Jasper was always 100% involved in the project and he was someone you can count on to finish his work.

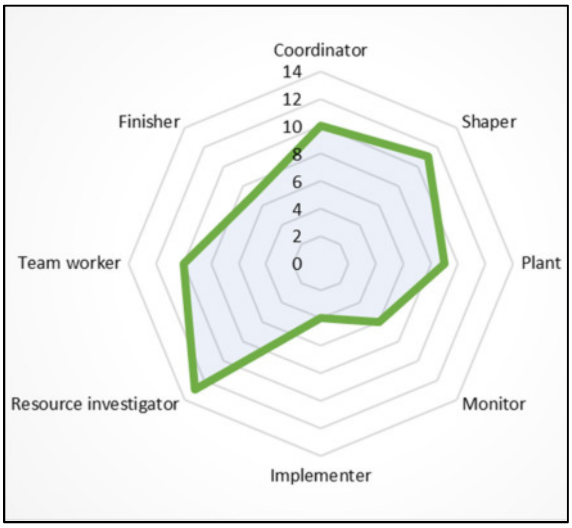
Jasper van Dreumel	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	1	1	0	3	2	1	1	1
2	1	2	2	1	1	1	0	2
3	2	2	1	1	0	2	1	1
4	1	1	2	1	1	2	1	1
5	1	1	1	1	2	1	2	1
6	1	2	1	2	1	1	1	1
7	1	2	2	1	0	1	1	2
Total	8	11	9	10	7	9	7	9
	think				act			



Michael Haimerl

The profile of Michael indicates, that he is a good ‘team worker’ and ‘coordinator’.

Michael Haimerl	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	1	1	1	2	1	1	2	1
2	1	1	2	1	0	2	2	1
3	2	1	1	2	0	2	1	1
4	1	1	2	0	1	2	3	0
5	0	2	1	0	1	3	0	3
6	1	2	1	1	1	1	2	1
7	4	3	1	0	0	2	0	0
Total	10	11	9	6	4	13	10	7
	think				act			



This was reflected in his work by the leadership he showed in the first part of the project. Indeed, his investment in the project management and his communication skills made him a good chairman for the team. His ‘team worker’ aspect was also highlighted in the different tools he created for the team, for example the working time record and the project schedule. His ‘shaper’ part was also shown by the rigor of his work. For him it was always a duty to finish the given tasks. Because of his good leadership within the team and the seriousness of his work, Michael was able to motivate his team members to do their very best for the project.

The shown figures are excerpts and details out of the Belbin test profile of the team, which can be found in the appendix 2.

1.4.4 Mission and Vision of the Team

At each project start, the team should ask what is the fundamental purpose of it, why it has been developed and what is the long-term view.

The **'mission'** is to find the best solution to handle the plastic waste in the agricultural sector in the project region.

The **'vision of the team'** is to develop new methods, which help to reduce the amount of plastic waste in the agricultural sector and make this green business even greener.

2 Project Definition

2.1 Project Description

The agriculture in the Nordic area is composed of big agricultural exploitations but also small local farms. In most of the cases, these farmers do not have a necessary production for using silos. An available solution is using big plastic tubes for the storage of the grain. One advantage of this method is the storage of wet grain and therefore, no drying costs. In addition, the farmers do not have greater investments and the storage amount is flexible and only limited by the available area on the farm. However, this solution includes several problems. For example, the big tubes are not transportable because of their size. Once the big plastic tube is opened, it cannot be closed anymore, which is a problem for the conservation of the grain. However, the main problem is the afterlife of this technology, because nobody has implemented a program to recycle the used foils yet. The big tubes are just burned in the waste incineration plants or given to a landfill, which is the worst solution for the environment. The aim of the transnational project 'Wet Grain in Package' is to find a new solution of grain packaging, using smaller bags which will be transportable and so tradable between the farmers. These smaller bags should be environmental friendly and that is the purpose of this project of the team 'Korntainer'. The goal is the 'Investigation about the most sustainable handling of the plastic waste which arises from the packaging process of wet grain'. More in detail, the team must find the most sustainable type of plastic for these bags which should have a commercial value after its using to avoid any combustion or landfill of the waste.

2.2 Organization and Structure within the Project Team

The EPS charter constrains the team to choose a chairman and a secretary. You can find the details of the assignments and an overview of the special working fields in the Table 3.

Table 3: Organization and structure within the team

Name	Function (Sept.-Oct.)	Function (Nov.-Dec.)	Special work field
Michael Haimerl	Chairman	Researcher	Project Management tasks / Guiding through the Initiation & Planning stage
Hugo Bonnafous	Secretary	Researcher	Contact with expert and specialized company / Help in team member profile redaction
Jasper van Dreumel	Researcher	Chairman	Research about the after-usage of plastics / Review of the work
Gijsbert Houtman	Researcher	Secretary	Research for the best available type of plastic / responsible for the elaboration of the case study

3 Project Initiation

3.1 Project Charter

A project charter determines the scope, the objectives, and participants of the project in form of a written and signed document. It is recommended to create this document in an early stage of the project. The following Figure 5 is an extract of the original document, which can be found in the appendix.

Project Charter			
Project name:	Wet Grain Package	Date:	09/14/2017
Stakeholder:	- Swedish Machinery Testing Institute (Umeå) - Swedish University of Agricultural Sciences (Umeå) - Novia University of Applied Sciences (Vaasa) - Norwegian Institute of Bioeconomy Research (Tjøtta) - Farmers in the Nordic countries (Botnia-Atlantic)	Project lead:	Project Team "Korntainer" with supervisor Niklas Frände
Project Description: *High-level description of project*			
Investigation about the handling of the plastic waste which arises from the packaging process of wet grain.			
Business Need: *Reason for the project, external, internal (strategically intention)?*			
Usually the farmers collect the grain for their livestock and dry it then in silos. If they need some food for the livestock, they crimp it and then they must mix the dry grain with some water again before they can feed it to their livestock. This is an established technique, which is used in all the countries around the world. The traditional way of storing grain is the most effective technique for huge cultivated areas and farms with a big livestock. For farms and cultivated areas, which are very small, like in the region of the stakeholders (Norway, Sweden, Finland), this traditional technique is very expensive. There is only a small quantity of grain, which should be dried and stored and huge costs for the drying process itself. To increase the competitiveness of the farmers in the Scandinavian			

Figure 5: Project Charter – extract 1

At the beginning, a project charter includes the project name, the date, the project lead and a list of the stakeholders, which have an interest in the outcome of the project. Furthermore, the charter states a high-level description of the project, which means to name the goal of the project or what the project is about in a few words. The reason for the project and the strategical intention can be found in the 'Business Need'. In the case of this project work, the business need of the bigger project 'Wet Grain Package' is the same as it is for this sub-project, but the sub-project focusses on the 'Investigation about the most sustainable handling of the plastic waste which arises from the packaging process of wet grain'. Therefore, the business need in this project charter describes the situation for the whole project with a focus on the responsibility for the environment, which means the avoidance or the reducing of single-way plastic materials.

The next Figure 6 shows the project goals, which are determined by using the methodology SMART. This means a **s**pecific, **m**easurable, **a**ccepted, **r**ealistic and **t**ime bound goal definition.

Project Goal: *SMART*
The whole project "Wet Grain in Package" is done by a cross-border cooperation of Scandinavian Institutes. A sub-project was given to the student group "Korntainer" of the Novia University of Applied Sciences in Vaasa. The goal of this project is the "Investigation about the handling of the plastic waste that arises from the packaging process" within 4 months or one semester. This goal includes three sub-targets, which are formulated in form of questions: - Which possibilities exist for the inner/outer bags after use? Could the material be refined into usable products which have a commercial value? - How clean does the plastic need to be for each alternative? What technologies are available for cleaning the plastic? Is it economically feasible? - How mature is the technology of edible plastics? Could the inner bag be made from edible plastic for the livestock? Finding solutions for the main goal and the sub-targets should be done as a basic research. The focus of the research is on the practical realization of the solutions regarding the needs of the farmers in the project region 'Botnia-Atlantic'. Therefore, the commercial aspect takes a priority in the project elaboration.
Requirements: *High-level list*
The suggested solution needs to fulfill requirements such as recyclable raw material, free from toxins, resistance against internal and external influences (e.g. weak acids, tensile stress, sunlight)

Figure 6: Project Charter – extract 2

The main goal of this basic research, the investigation about the handling of the plastic waste, is divided into three sub-targets. These targets are focused on the commercial aspects of the waste handling and the technology. In addition, they create the framework of this project and help to avoid a scope creep. Beside the description of the goals and the setup of a framework for the project, the project charter includes a high-level list of the requirements for the suggested solutions. Both definitions were extremely significant to lead the first research work into the right direction and to make sure, every project participant is aware of the aim of the project work.

The last extract, Figure 7, shows another important text passage of the project charter. It is the schedule with the defined milestones. These milestones were an orientation and an instrument to measure the work progress. When one milestone was reached, the project team came together and reviewed the work progress and whether the project is in time or not. In this project, the milestone could be an event, which would have a substantial influence on the research work, as well as a sub-target or the main goal. A further point is the determination of possible project risks, which are formulated in form of a high-level list. There was a high degree of certainty, that this list did not include all the risks, which the project team would face during their work. However, these presumptions helped to be aware of these risks from the beginning of the project and to develop first measurements to avoid or to deal with these risks. This list was also a basis for the risk-analysis, which was developed during the planning phase of the project management and the project work.

Schedule:	
Start Project:	09/07/2017
Milestones:	• 10/04/2017 Telephone conference with Hans Arvidsson • 10/05/2017 Signed Project Charter • 10/13/2017 Completing the Planning Phase • 10/24/2017 Midterm Report • 11/17/2017 Finishing the work on the given questions • 12/08/2017 Finishing the conclusion with presentation of own ideas • 12/12/2017 Finishing the review of the project report • 12/18/2017 Final Report
End of Project:	12/19/2017
Project Risks:	*High-level list (Basis for Risk-Analysis)*
No suitable information for the research; time delay; scope creep; no support of project members or possible stakeholders and suppliers	
Justification:	*(e.g.Feasibility Study, Cost-Benefit-Analysis, SWOT-Analysis)*
Several countries around the world started campaigns to reduce the plastic waste in the agriculture sector by using new technologies of packaging or by recycling the waste. The society supports these environmental friendly ideas. New products need to be “green” to be accepted and to be successful. The complete industry is aware of this change in the product conception and because of the great demand, green technologies are affordable now. A feasibility study, which was worked out before by the project team, shows a positive result for the idea and the project work itself. A further execution is recommended.	

Figure 7: Project Charter – extract 3

The last point in the project charter is the ‘Justification’. Basis for the justification is a previous feasibility study of the project, which helped to examine whether the project would face great constraints or not. For this project, the project team did not expect greater challenges and therefore, the start of the project and the execution of the project were recommended.

Mister Frände, the Project Supervisor, signed the project charter on the 5th of October. All participants of the sub-project, the project team ‘Korntainer’ and Niklas Frände, agreed to refer to this project charter during the project work in the next four months.

3.2 SWOT-Analysis

The SWOT-analysis uses the results of an environmental analysis to compare the negative and the positive aspects and their impact on the project. **SWOT** is an acronym for **S**trengths, **W**eaknesses, **O**pportunities and **T**hreats and it is one of the most important tools for a strategic analysis. The analysis is made by using a matrix with an ‘External analysis’ side and an ‘Internal analysis’ side. The external analysis shows the opportunities and threats for the project work, which are caused by the environment (e.g. laws, end user, location of the application areas). The internal analysis points out the strengths and weaknesses regarding the work structure (e.g. skills of the project team members, provided data bases).

SWOT - Analysis Investigation about the handling of the plastic waste which arises from the packaging process of wet grain	**Internal analysis**	
	strengths	**weaknesses**
	> the association of R&D institutes has access to various own programs or reports and the expert knowledge of their employees > the Swedish Machinery Institute has a special expert, who has experience as a farmer > the project team consists of young people with motivation and specific knowledge	> limited time for the realization of this R&D project > project team has never worked in this constellation before (no experience as a team) > field of research (agriculture sector and plastic industry) is new for the team
External analysis – **opportunities**	***"expand"***	***"catch up"***
> no existing programs to reduce waste or to create a commercial value for waste in the project region (exception: Sweden, but only an organized waste disposal structure) (innovative) > plastic waste is an unwanted thing for the 'green' agriculture sector, but there is no sustainable waste handling solution	> intensify cooperations and projects of the R&D institutes with the agriculture sector and in some cases with single farms in the project region, especially in the new field of research 'Handling of plastic waste in the agriculture sector'	> better support and a detailed planning for the fields of research since its inception by the project manager (or supervisor) > providing of a database for the team or a short dossier to inform the team about news and changes in the field of research by the project manager (or supervisor) > fast communication, e.g. with experts of other project partners of 'Wet Grain Package'
threats	***"secure"***	***"avoid"***
> the agriculture sector in the project region does not have the required structure (small farms, not connected) and technology (no industrial character of the single farms) to collect the plastic waste in an adequate volume to bring it to the local recycling companies (no or poor use of standard waste disposal structures) > the investigated solutions should be affordable for the farmers	> Arrange several meetings with companies and farmers to guarantee the realization of the investigated solutions > Keep in contact with the Swedish expert, who is responsible for the construction design of the packaging machinery for the new big bag idea	> good management and monitoring & controlling to avoid "scope creep" by working out too many details and not being focused on the project goals, because there are so many unclear subjects

Figure 8: SWOT-analysis

The SWOT-analysis in Figure 8 offered a critical view on the own project and confronted the team with the question of the own weaknesses. The task for the team was:

‘Maximize the benefits from the strengths and opportunities and minimize the losses from weaknesses and threats.’

This analysis of the interactions between the various combinations helped to determine strategies for the future. The strategies for the project at issue are written down in the center of the matrix and their titles (‘expand’, ‘catch up’, ‘secure’ and ‘avoid’) show for what the strategy stands for.

The strategy ‘expand’, which should increase the value of the strength-opportunity combination, suggested to intensify the cooperation and projects of the Research & Development institutes with the agriculture sector in the project region, especially in the new field of research ‘Handling of plastic waste in the agriculture sector’. There are still only few projects in this field of research and the agriculture sector, as a ‘green’ business, will gain many advantages out of the development of sustainable solutions for the packaging process.

The title ‘secure’ meant that the project group should pay attention on the needs and requirements of the farmers in the project region. The agriculture sector in the project region does not have an industrial structure and therefore, there should be a gapless communication with the end-users to keep a practical point of view.

With the ‘catch up’ strategy, the project team wanted to avoid future time delays because of unstructured and not prepared project management. The team consists of young, motivated students, who have never worked in this constellation before and who do not have experience in the project subject. Such a team needs a well-prepared data base to inform them about the main aspects of the project and clear defined objectives to support a fast start of the project work. The strategy was a recommendation for the work of the project manager to ensure that he takes care of these aspects in the following work.

The main task out of the ‘avoid’ strategy was a good project management with focus on the monitoring & controlling part. Without experiences in this field of research and with so many unclear subjects, the probability of a scope creep was high. This increase in the scope would cause a time delay and because of the time restrictions, the project management had to focus on the supervision of the project work of the individual work of the team members.

The SWOT analysis was also used as a basis for the risk analysis in the ‘Project Planning’.

3.3 Stakeholder Analysis

The stakeholder analysis offered a good overview about the individual interests of the stakeholders and their influence on the sub-project of the student group 'Korntainer'. In addition, the stakeholder analysis provided the following outcome:

- Identification of possible resistance from individuals, groups or institutions in the project initiating phase
- Development of measures to achieve win/win situation

At first, the project team analyzed all project stakeholders and their special roles, interests and expectations. The subsequent process was the evaluation and prioritization of the stakeholders and to decide how the communication with these groups or persons should be. The last action was the development of win/win strategies, which should help to increase the efficiency of the project work or to get more information for the participants.

There are several different parties interested in the realization of the project work of the student group 'Korntainer'. The following Figure 9 shows an abstract display of the stakeholder structure.

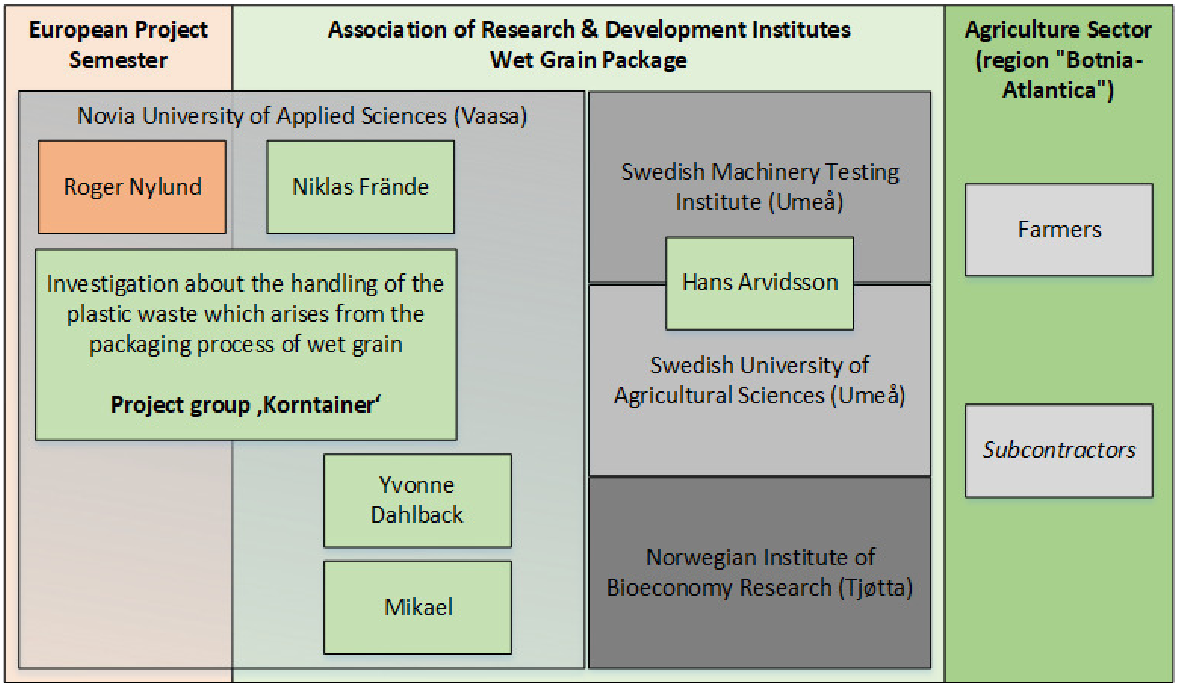


Figure 9: Structure of stakeholders

Most of the stakeholders, for example the Swedish Machinery Testing Institute, are project participants themselves and they are working for the main project 'Wet Grain Package'.

There are only few or no connections to the end-users of the technology, for example the farmers in the project region, because the main research project ‘Wet Grain Package’ started only a few months before the sub-project of the student group. During the four months in Finland, the team could not create any new connections either. This was caused by language barriers and the time constraints. For the future, it is recommended to create these connections, but currently there is only the expert of the Swedish Machinery Testing Institute, Hans Arvidsson, as a source of information. He has an own farm and develops the packaging machinery for the storing process of wet grain in big bags. The following Table 4 shows the goals, motivations or interests of the other stakeholders and if their influence and their interest in the project were low, middle or high.

Table 4: Goals, motivations and interests of the stakeholders

Stakeholder group	Goals, motivations, and interests regarding the sub-project of the student group 'Korntainer'	Influence	Interest	Action
Swedish Machinery Testing Institute (Umeå)	Suitable inner foil for the new big bag packages for wet grain to make adjustments at the new developed packaging machinery	Middle	Middle	Keep satisfied
Swedish University of Agricultural Sciences (Umeå)	Green Footprint' of the new wet grain storage idea to increase the probability of a successful project implementation in the project region	Low	Low	Monitor
Novia University of Applied Sciences (Vaasa)	Research results regarding sustainable packaging ideas for wet grain and their classification	High	Middle	Manage closely
Roger Nylund (Coordinator European Project Semester)	Comprehensible and logical structur of the project management and the monitoring and controlling	High	Middle	Manage closely
Niklas Frände (Supervisor of the student project team)	Logical structur of the reports (Mid-Term Report and Final Report) and research results regarding sustainable packaging ideas for wet grain	High	High	Manage closely
Norwegian Institute of Bioeconomy Research (Tjøtta)	Green Footprint' of the new wet grain storage idea to increase the probability of a successful project implementation in the project region	Low	Low	Monitor
Farmers in the Nordic countries (Botnia-Atlantic)	Cheap and simple way of disposing the plastic waste without investments in disposal or cleaning technologies	High	Low	Keep satisfied

The whole analysis helped the team to decide whether there should be a careful communication and a focus on the stakeholder’s requests or not. Various possible actions were developed, like ‘Manage closely’, ‘Keep satisfied’ and ‘Keep informed’. These terms describe the intensity of the communication with the stakeholders and are defined in detail in the communication plan in the chapter ‘Project Planning’.

3.4 Feasibility Study – Telos

The project management used the feasibility study to summarize the complete insights of the project definition and initiation phase as well as the results of the accompanying research to create an information base for the further project planning phase. This study can be also used for demonstration purposes and finishes the chapter ‘Project initiation’. In the following image, the feasibility of the project work in various areas in the form of a TELOS structure. TELOS is the abbreviation for ‘**T**echnical feasibility’, ‘**E**conomic feasibility’, ‘**L**egal implementation’, ‘**O**rganizational implementation’ and ‘**S**cheduling, time implementation’ can be seen. All the insights of the previous analysis are structured in the same way. Figure 10 was also an important part of the project charter and basis for the justification and the recommendation of the research team ‘Korntainer’.

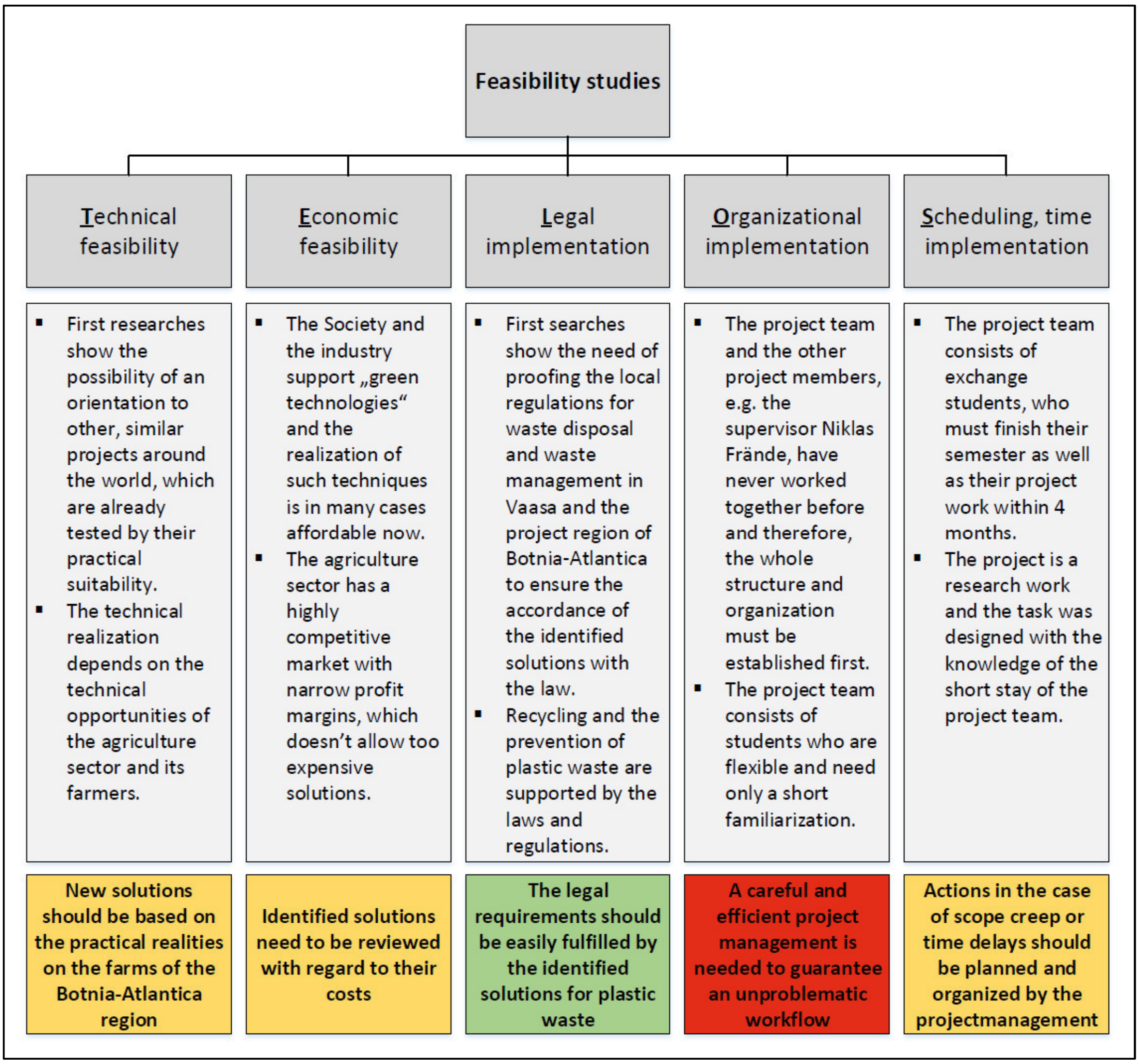


Figure 10: Feasibility study TELOS

The colors of the single parts of the feasibility analysis signalize the estimated difficulties the project group could have faced during their research work. First studies showed a low expectation that the legal regulations cannot be fulfilled by the investigated solutions for the handling of plastic waste. This part of the TELOS analysis is marked with the color 'green'. In contrast, the organizational implementation is highlighted with the color 'red'. According to the consensus opinion of the participants, the focus of the project management should be on a careful implementation of structures and regular working processes for the team. As already mentioned in the previous SWOT analysis, the group has never worked in this constellation before and therefore, there was a need of structures to form an efficient project team in a short period of time to avoid any scope creep or time delays. The conclusion of the analysis regarding the scheduling and time implementation, which is marked 'yellow', suggested a fast intervention of the project manager for these points. The handling or management of a scope creep or a time delay requires a detailed action plan. The project management has focused on these plans and for example elaborated a detailed scope and time management in the chapter 'Project Planning' as well as efficient monitoring & controlling tools in the Chapter 'Project Execution'. The last two parts of the feasibility study, the economic and the technical feasibility, are closely linked. The agricultural sector in the project region does not have an industrial character. The farms are small, and the farmers have only low margins by trading their products. The investigated solutions to handle the plastic waste which arises from the packaging process of wet grain had to be affordable and technical feasible and the team should always remember these two aspects during their research work. For this reason, these two parts are highlighted 'yellow' and they were handled carefully by the project management in the monitoring & controlling stage of the project.

Beside of these summarizing qualities of a TELOS analysis, the project team could use it as another good basis for the risk-analysis in the chapter 'Project Planning' together with the SWOT analysis.

4 Project Planning

4.1 Scope Management Plan

A scope management plan uses the data of the project charter as an input. Out of the project mission and the defined framework of the project, the project management can develop the plan. This plan describes the process of preparing the scope statement, the process of creating the work-breakdown structure and the process of how deliverables will be verified and accepted. Outputs of these scope management actions are the project scope statement and the work-breakdown structure.

The insights of the previous project management phases, the ‘Project Definition’ and the ‘Project Initiation’, were used to create the scope statement. This is a detailed version of the high-level description of the scope in the project charter. In the project charter, the task of the research work is described as an ‘Investigation about the handling of the plastic waste which arises from the packaging process of wet grain’. (refer to Project Charter) In a more detailed form, the task can be characterized as the ‘Investigation about the most sustainable way of the handling process of the plastic waste which arises from the packaging process of wet grain in the project region in consideration of the financial affordability and the technical realization’. This main objective is subdivided into three sub-tasks:

- Research about possibilities for the inner bag after use with a focus on the creation of a commercial value through these investigated solutions
- Description of the required purity degrees and the related cleaning technologies for the developed solutions
- Clarification about the usefulness of edible plastics as packaging materials in the agriculture sector

Out of these achievable goals, the project team created the framework of their research work in consultation with their supervisor Niklas Frände and the Swedish expert Hans Arvidsson. The project of the team ‘Korntainer’ is a basic research and therefore, it should be an information base for the other projects of the whole research group ‘Wet Grain Package’ regarding the handling of the plastic after use. The focus was on the special needs of the project region, but in their report and conclusion the team also worked with the results out of analyses of other similar projects around the world. The type of the scope was a mixture of a work- and process-orientation and an orientation toward functional requirements, but the focus was not on the development of a new product. It was more recommended to use standardized processes and solutions to ensure the practical realization and to avoid possible high costs.

In addition to this scope statement, a work-breakdown structure visualizes what the project work is about and what the borders of the research were. In this structure, the tasks to achieve the determined goals were divided into smaller work packages. The following Figure 11 shows the project management related work-breakdown structure.

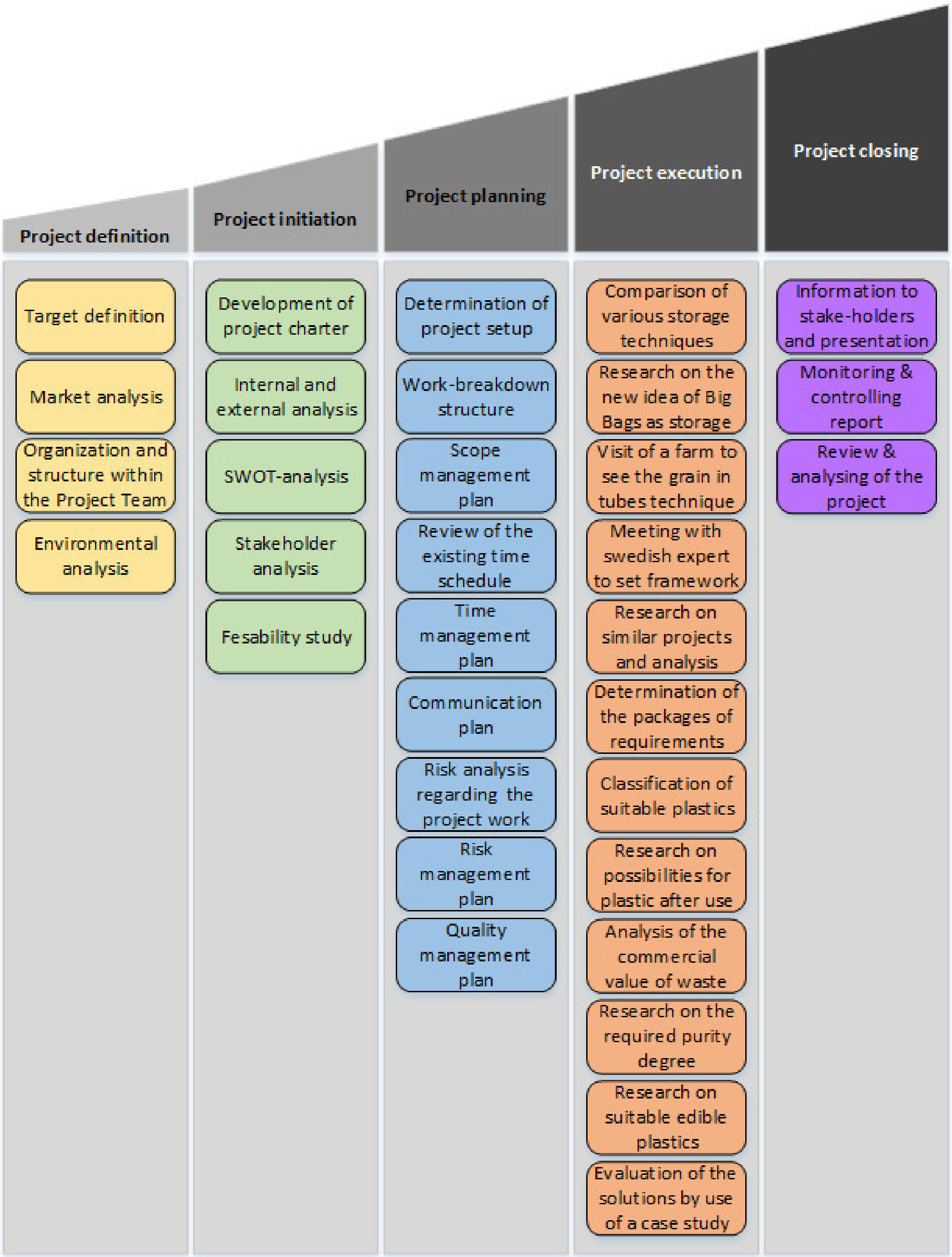


Figure 11: WBS - project management related

The project team decided to create two work-breakdown structures. The first one is mainly to determine the required management tasks. The project is structured into five steps and every finish of a step or phase is a main milestone. The content of the project definition phase, the project initiation phase and the planning phase are standardized, and follows the instructions given by the PMBOKGuide and Mister Roger Nylund in his 'Project management' classes.

For the planning of the project execution phase, an additional work-breakdown structure was worked out to determine this important chapter in detail. This work-breakdown structure focuses on the research work and its elements. The following Figure 12 shows the determined work packages for each element of the research work. It can also be looked up in the appendix.

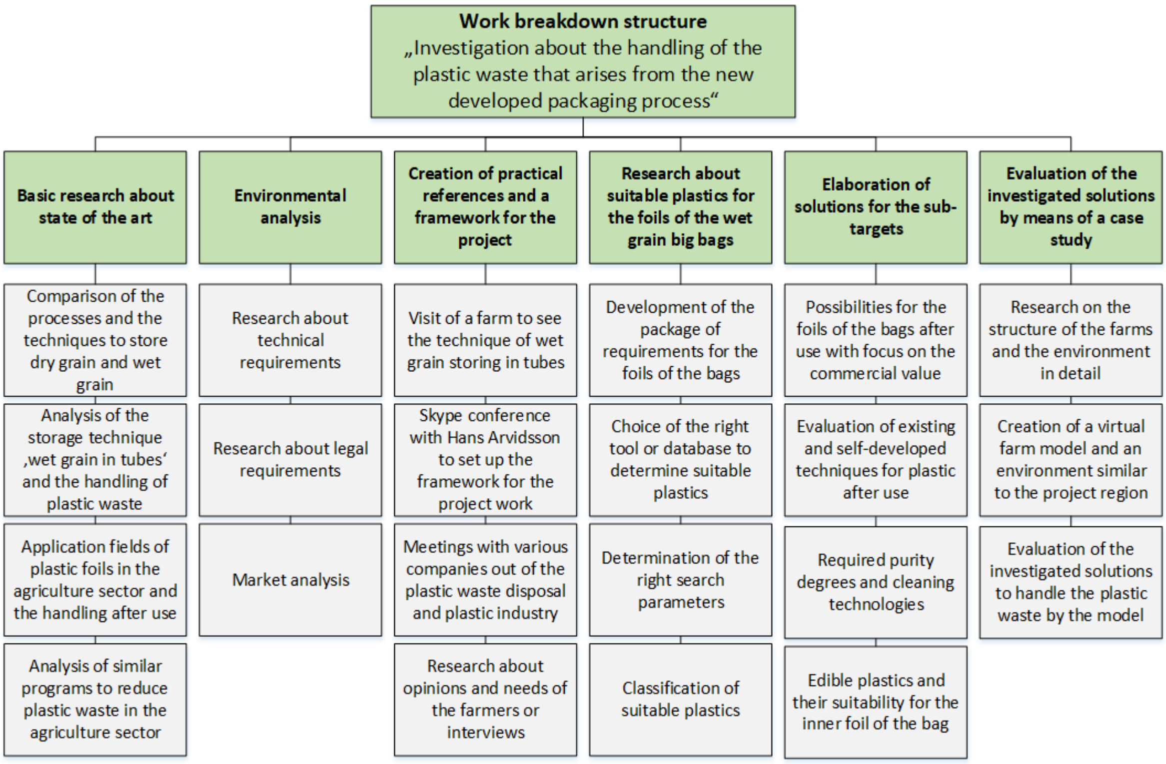


Figure 12: WBS – research work related

Through the findings and the results of the work-breakdown structures (project management related, and research work related), it is possible to elaborate the time management plan, which will follow in the next chapter.

4.2 Time Management Plan

The time management plan was the most important document of this research project. Strict time restrictions could cause a substantial risk for the project success because a project delay could not be compensated by adding extra days or using more resources. Including buffer times is only possible by using extra working hours at the weekends, which were planned as rest time for the participants. The students were working on this project as a team for four months. Time was, beside of the need to implement an efficient working structure, the biggest constraint of this project and made a gapless information flow between all the project participants necessary to avoid any time delays. One highly recommended action was the use of Microsoft Project and in addition, an excel sheet with similar data to provide a clear planning and a project plan for all project participants. The time schedule and project plan were reviewed regularly by the project manager and the project participants were obliged to remind the manager of their labor input in detail as soon as possible. Milestones and weekly meetings gave the project participants a good overview at which point of time the project stood. First milestones were determined in the elaboration of the project charter and can be seen below.

Milestones:

- 10/04/2017 Telephone conference with Hans Arvidsson
- 10/05/2017 Signed Project Charter
- 10/13/2017 Completing the Planning Phase
- 10/24/2017 Presentation of the Mid-Term Report
- 11/17/2017 Finishing the work on the given questions
- 12/08/2017 Finishing the conclusion with presentation of own ideas
- 12/12/2017 Finishing the review of the project report
- 12/18/2017 Presentation of the Final Report

These milestones should be reached at a determined date. They were given by the project supervisor, Mister Niklas Frände, and the organizer of the European Project Semester, Mister Roger Nylund as well as by the manager of the team and were specific. Parallel to these main milestones, the project management used the project phases of the work-breakdown structure (project definition, project initiation, project-related planning, product-related planning, project execution and project closing) and their finishes to create further smaller, but also important milestones. Because of these considerations, the project management used distinct colors in the Gantt chart to separate the phases clearly.

The estimation of time for the phases 'Project definition', 'Project Initiation', 'Project planning' was difficult for the project team. Only a short-term planning for these six weeks existed in the beginning, which contained events, which did not take longer than two days. Several factors prevented the team to do a long-term planning for these phases:

- The team forming phase took a long time with intensive part-time work in StrengthsFinder-workshops, because most of the team members did not know each other from before and they are from different cultures with different languages. This phase was necessary, but long-term planning for this was useless.
- The team members needed time to get used to the new environment and the provided work places in the university. Plans were modified from one day to the next, always following up-coming events and activities. Planning was not possible without any stable structures for the team.
- The objectives and the framework of the project have not been clear until the telephone conference with Hans Arvidsson took place at the October 4th. Without restrictions for the project, the team could not do an accurate planning of all required work packages and therefore, not plan the duration of the processes.

After this telephone conference with the Swedish expert for the design of the packaging machinery to store wet grain in Big Bags, Mister Hans Arvidsson, who could support the team with some important information, the team was able to develop a more long-term planning. Because of this event, the project team reviewed the previous scope determination and the schedule. The milestones were also adapted and equipped with additional information to follow the new direction of the project. The information of the chapters 'Project Initiation' and 'Project Planning' in this report was mainly based on this current development in the project research.

For the new long-term planning, the project team needed to estimate the possible duration of each work package and clarify the dependencies and sequences of the future tasks. To avoid the risk of time delays and their consequences for the whole project duration, the project management team used time buffers. For the estimation of the time for each of these work packages, the team used the two work-breakdown structures as a source for analyzing the single work packages. By means of the both time estimate methods, the 'analogous estimates' on the one side and the 'Three-point- estimates' method on the other side, every work package got a time information. For the 'analogous estimate', the work of each team member was analyzed by the project manager. Combined with the manager's experiences of former projects, most of the time estimations were done by this analogous estimate by comparison with similar processes. A few estimations required the 'Three-point-estimates method'. This method forces the user to think about the shortest time, the longest time and the likely time. The formula can be looked up below.

$$\frac{(\text{Shortest time} + 4 \times \text{likely time} + \text{longest time})}{6} = t\,(\text{estimated})$$

This tool is useful, but it requires also some experience in the estimation of the time needed for a process. Because the team has never worked in this constellation before, this time planning had a high level of uncertainty. The project management was aware of this fact and monitored and controlled the elaboration of these work packages closely.

After combining every work package with an individual time length and structuring all work packages regarding their dependencies, the project management elaborated the time schedule in Microsoft Project, which can be seen in a shortened version in the Figure 13.

Task Name	Duration	Start	Finish
PROJECT DEFINITION	**87 hrs**	**Thu 07.09.17**	**Thu 21.09.17**
PROJECT INITIATION	**88 hrs**	**Thu 21.09.17**	**Thu 05.10.17**
PROJECT PLANNING	**48 hrs**	**Fri 06.10.17**	**Mon 16.10.17**
PROJECT EXECUTION	**312 hrs**	**Mon 16.10.17**	**Fri 08.12.17**
PROJECT CLOSING	**32 hrs**	**Mon 11.12.17**	**Fri 15.12.17**
Preparation of the Final Report Presentation	8 hrs	Fri 15.12.17	Fri 15.12.17
Presentation Final Report	0 hrs	Mon 18.12.17	Mon 18.12.17

Figure 13: Project management phases

The program Microsoft Project provides a presentation of the schedule as a Bar chart, or also called Gantt chart (Figure 14). This visualization made the planning easier, because gaps in sequences or mistakes could be seen at a glance.

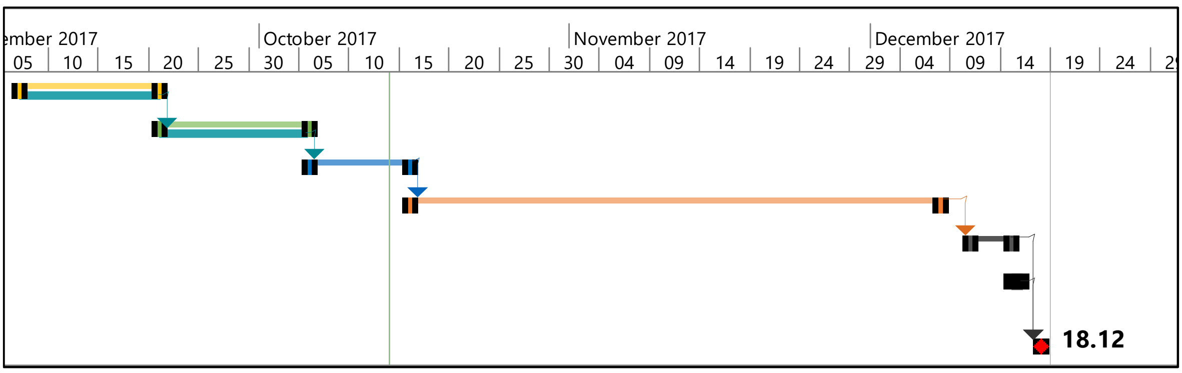


Figure 14: Gantt chart – project planning

Another visualization is the time line as shown in the following Figure 15. This time line is part of the Gantt chart's visualization and made it possible to navigate in the huge amount of data easily.

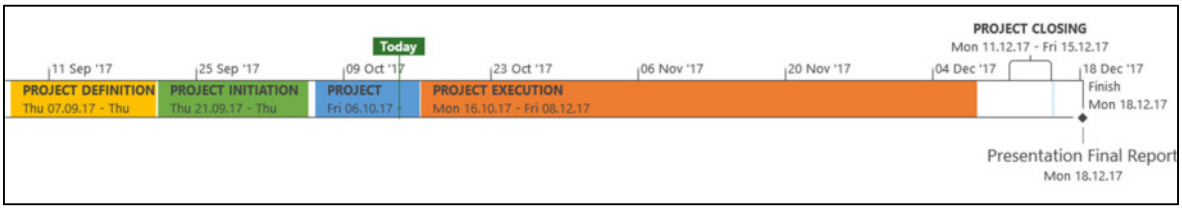


Figure 15: Gantt chart - time line

This schedule was reviewed regularly by the project management. The complete and detailed time schedule, which is designed as a Gantt chart, can be found in the appendix. In the detailed plans, the required resources can be looked up in an extra row. The resources are the number of project participants, who worked or would have worked at a single work package. For the estimations of the time, the project management considered that there could be benefits of a team work compared to individual work and that this could have positive effects on the working time for a task. Microsoft Project includes several useful tools, for example, the highlighting of the critical path and the view of the time schedule as a Gantt chart or a network diagram. But not every project participant was able to see the results of this program or analyze it, because only the first project manager and chairman of the team, Michael Haimerl, has a Microsoft Project license. Regarding this issue, the team agreed as a first step to export a portable document file (pdf) out of the Microsoft Project file, which can be used by every project member. As a second step, the project management provided another file in the Excel-format, which contains a monitoring & controlling tool, the Earned Value Analysis (EVA). This tool is based on the time schedule and includes the same information and it was reviewed in the same way as the Microsoft Project file. Every team member had access to Excel and therefore, to this file. This tool was a constantly available source of information. The monitoring & controlling file can be looked up in the appendix.

4.3 Communication Plan

A research work like the project of the team 'Korntainer' is based on communication. This does not mean only the communication between the team members, but also the communication with the environment. Without some organizational structure of the various communication channels, the probability of information loss or misunderstandings between the project participants is very high and that is why the team analyzed the communication and created a communication plan.

The basis for the communication plan was the previous stakeholder analysis, which was elaborated in the chapter 'Project Initiation'. The following Figure 16 shows the classification of the stakeholders and their influence and interest in the project work.

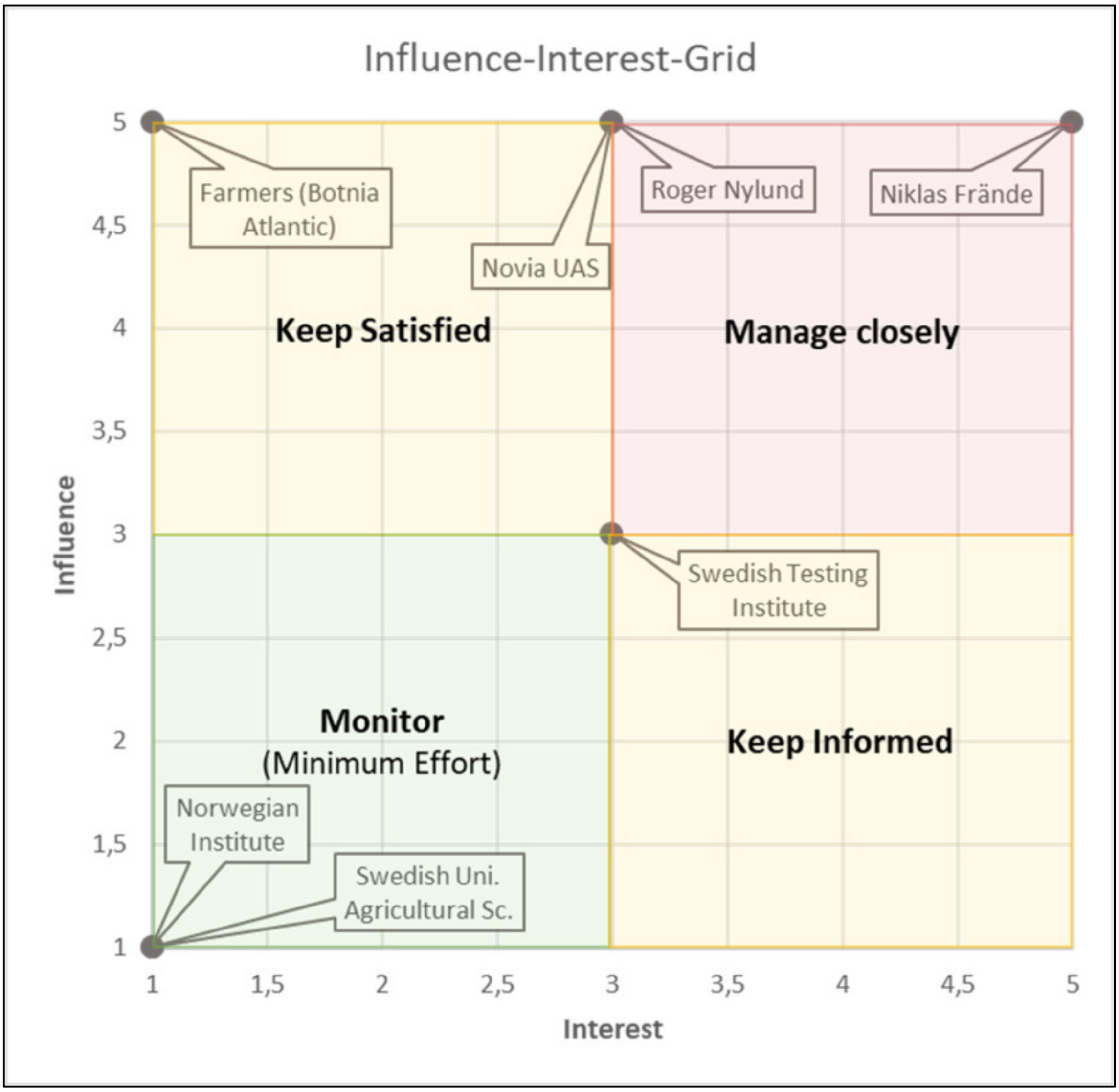


Figure 16: Influence-Interest-Grid of the stakeholders

The object and purpose of the stakeholder analysis was the identification of possible resistance from individuals, groups or institutions in the project planning and the project execution phase. With the communication plan, the team tried to satisfy the stakeholders by providing the necessary information in the required intervals. This should ensure an efficient communication and avoids greater problems and time delays because of the extra working time to fix the gaps in the information flow.

The following Figure 17 shows the communication plan with all the stakeholders and the recommended type of media. The intervals of the communication were not regulated, because there was only the supervisor, Niklas Frände, who should be informed about the work progress weekly in a meeting.

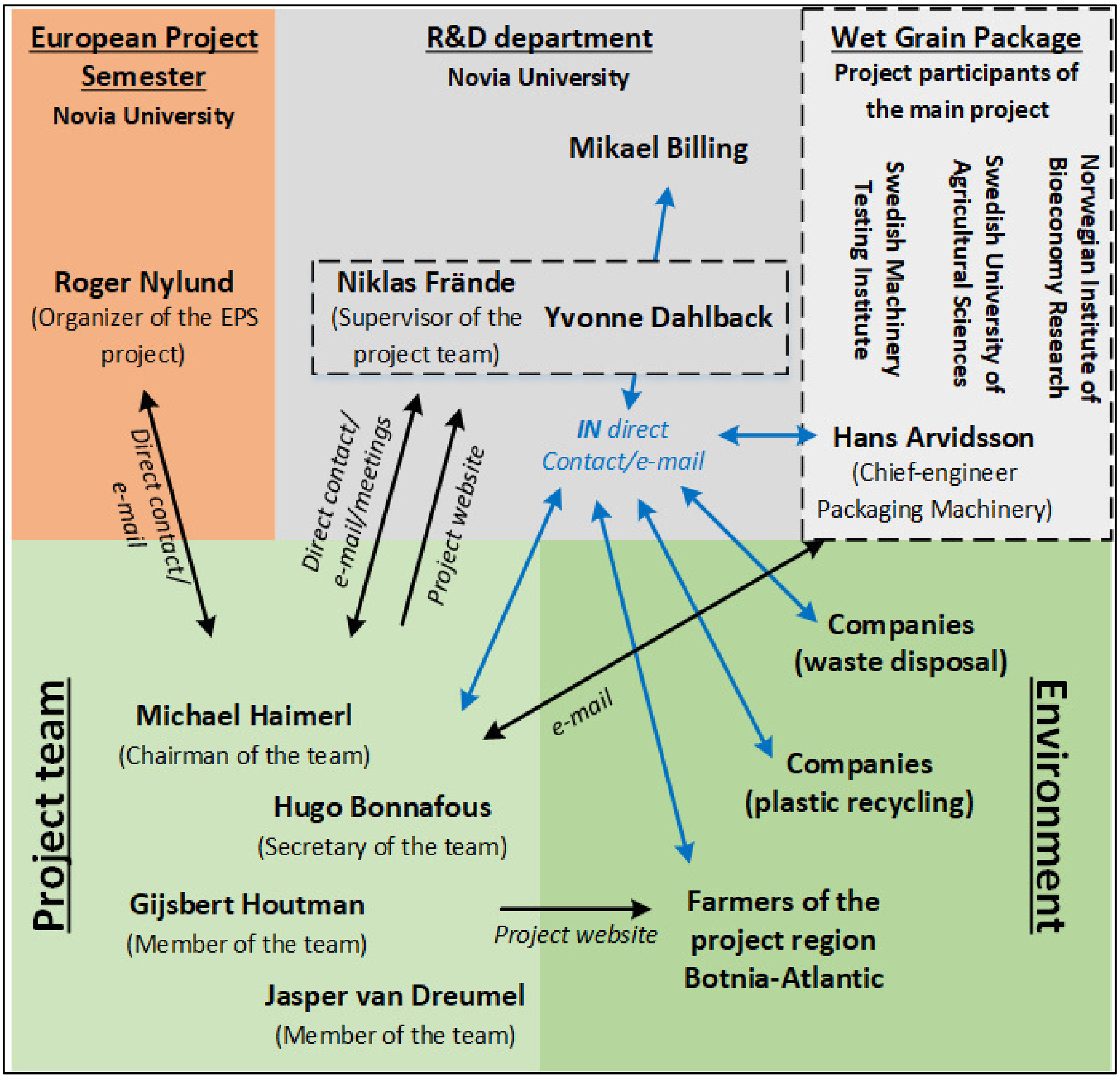


Figure 17: Communication plan

4.4 Risk Analysis

At the beginning, the team considered that the project could be affected by many risks which might occur during the project life cycle. The first step was to identify and describe all the potential risks in a brief brainstorming meeting. Afterward, the effect of the risks and the probability were combined with the impact. This enabled the rating of the risk priority and the preventive and corrective measures. The following Table 5 shows the risks identified by the project team ‘Korntainer’.

Table 5: Risk Analysis

	Risk	Description	Phase					Effect	Probability	Impact	Priority	Preventive Measure	Corrective Measure
			D	I	P	E	C						
1	**No suitable information** for the research	Innovative idea and poor information management in the agriculture sector	x	x	x	x		Increasement in time and difficulty to do research work	20%	39%	**LOW**	-	Own information acquisition
2	**Technically unfeasible**	No feasible solutions available because of lack of technology in the environment	x	x	x	x		Termination of the complete project	10%	89%	**MEDIUM**	Research about technical feasibility and requirements for farms	-
3.1	**Time delay** (regarding the planning)	Scheduling or time management was unappropiate and caused late starts		x	x	x		Complete project is late and cannot be finished properly	31%	84%	**MEDIUM**	Plan and define realistic milestones; accurate time management	-
3.2	**Time delay** (regarding the team behaviour)	Meetings must be cancelled/postponed because of missing participants	x	x	x	x		Complete project is late and cannot be finished properly	38%	76%	**MEDIUM**	Good communication and communication management	-
4	**Missing end user acceptance**	End user (farmers) are not interested in the new solutions to handle waste					x	Project work is useless and needs to be redone	34%	100%	**HIGH**	Research about the needs of farmers and focus on practical realization	-
5.1	Scope creep (regarding the elaboration of chapters)	Missing monitoring and controlling in the project leads to unwanted work				x	x	Project work will be extended and will cause a time delay	58%	53%	**MEDIUM**	Communication of clear targets for sub-tasks and review of work progress	Development of a 'Buddy-system' to get an individual monitoring/ controlling
5.2	**Scope creep** (regarding the whole project work)	Goals and/or sub-targets are bad communicated to the project participants			x	x	x	Project work does not have a clear result	48%	55%	**MEDIUM**	Enough time in the meetings to give all participants time to think about tasks	Regular review of the work and meetings with all team members
6.1	**No support of project members** (team internal)	Project members are not interested in the project work and a good elaboration	x	x	x	x	x	Lack of quality of the research work and the report	11%	90%	**MEDIUM**	Team-building measures and honest communication	Close monitoring of the team by the supervisor and the EPS project organisator
6.2	**No support of project members** (Novia Univer.)	Project members (e.g. supervisor/EPS organisator) do not have time/interest	x	x	x	x	x	No concrete guidelines can cause a confusion	30%	80%	**MEDIUM**	-	Meeting of all project participants to solve problems / issues in an honest climate
7	**No support of stakeholders**	Stakeholders (other institutes) don't have time/interest	x	x	x	x		Lack of information	33%	36%	**LOW**	-	Supervisor as communication channel for requests
8	**Missing communication with suppliers or companies**	Communication is difficult/not possible because of no time/ interest/language				x		Lack of information and no suppliers to recommend	59%	60%	**MEDIUM**	Supervisor, native project members as communication channel	List with possible alternatives of interesting companies
9	**No focus on practical realisation**	Missing focus on a practical realisation of the investigated solutions			x	x	x	Project work is useless and needs to be redone	53%	78%	**HIGH**	Critical review of goals and project work by supervisor and team / focus on practice	-
10	**Investigated solutions are too expensive for farmers**	No or poor research work about the related costs				x		Project work is useless and needs to be redone	45%	65%	**MEDIUM**	Focus on the commercial aspect and add of safety factors in calculations	-

The Figure 18 shows that the ones which are marked with a red color are the ones which need to be monitored constantly because of their high relevance. If these risks have occurred, they would have had a huge impact on the project. The risks which are highlighted in yellow and green would have had a lower impact on the project and the team did not need to control them constantly.

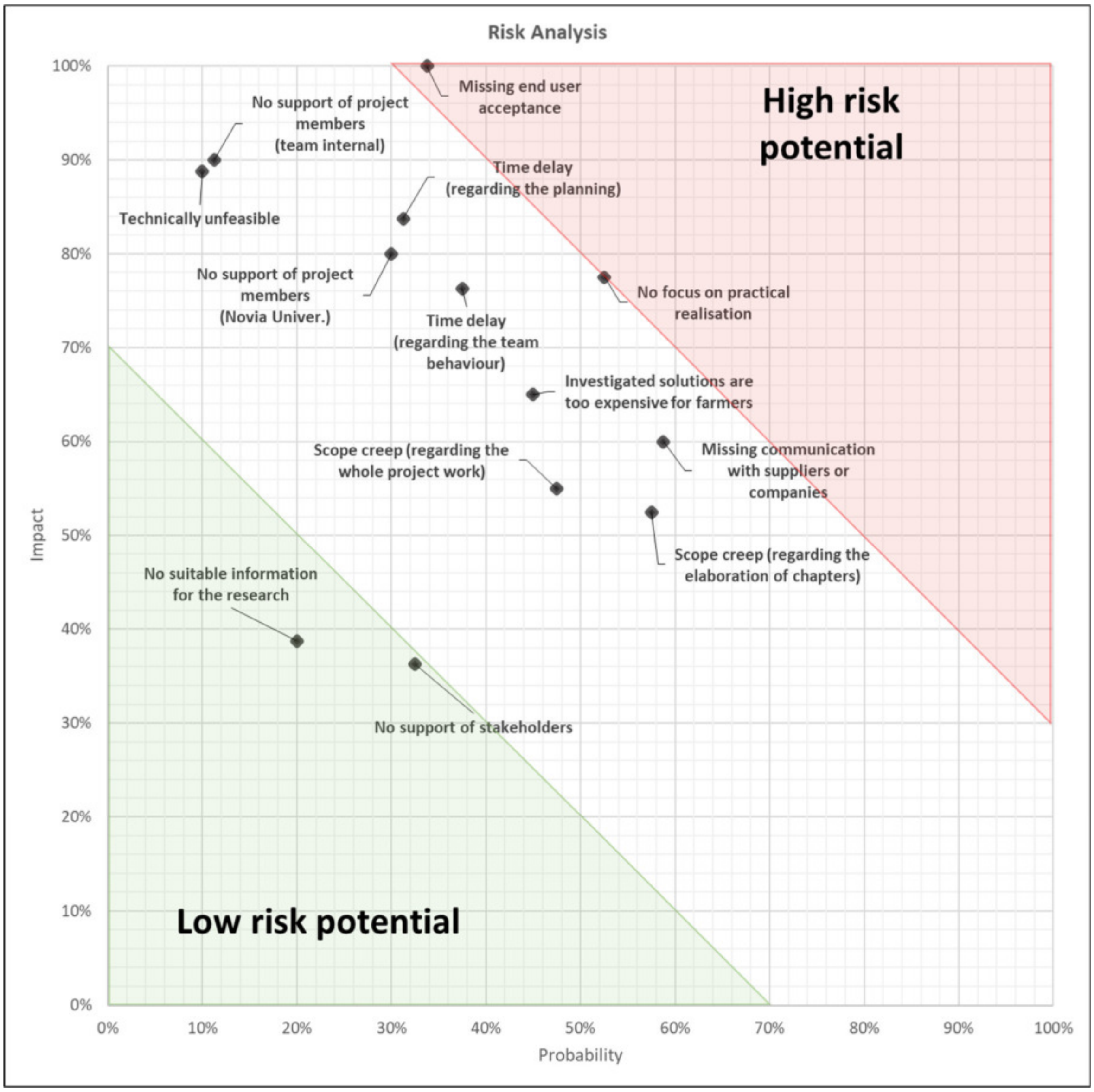


Figure 18: Impact-Probability diagram

The risk analysis made the project manager of the team 'Korntainer' aware of specific areas, which required his special attention. If he identified an upcoming risk during his monitoring & controlling tasks, he would have been able to rely on the formulated preventive and corrective measures.

4.5 Quality Management

Parallel to the time, the project team had to take care of the quality. To assure quality is a critical part of any project. Such a research work consists of a final report with all the investigated solutions and the conclusions and a huge amount of data. Without any quality management and feedback, the single project members might struggle with their own, individual goals and ideas for the project work. Beside of a decrease in the quality of the language or the content, there could be an increase in scope and required time, because the single person wants to work further on an idea, which has already been well explained. At the end, the project team might elaborate a detailed report, but this work would not suit the stakeholders' needs or their expected quality levels. These thoughts show how important quality management is for the success of the whole project. But it was very difficult to control the quality of all the data by one person. Otherwise it is likely that a review of the work by the whole team in regular meetings would have been time-consuming. To ensure that every project participant gets a feedback for his work and that this feedback is efficient, the team needed a new quality assurance system.

The new tool was called 'Buddy Review System'. The team consisted of four members and every person had one buddy out of the team, who was responsible for the review of the work. This constellation should change every week to ensure a homogenous feedback and review system. The following Table 6 shows the system for the last eight weeks.

Table 6: Buddy Review System

	The Project Member is responsible for …							
Project Member	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14	Week 15
Hugo Bonnafous	Jasper van Dreumel	Gijsbert Houtman	Michael Haimerl	Jasper van Dreumel	Gijsbert Houtman	Michael Haimerl	Jasper van Dreumel	Gijsbert Houtman
Michael Haimerl	Hugo Bonnafous	Jasper van Dreumel	Gijsbert Houtman	Hugo Bonnafous	Jasper van Dreumel	Gijsbert Houtman	Hugo Bonnafous	Jasper van Dreumel
Gijsbert Houtman	Michael Haimerl	Hugo Bonnafous	Jasper van Dreumel	Michael Haimerl	Hugo Bonnafous	Jasper van Dreumel	Michael Haimerl	Hugo Bonnafous
Jasper v. Dreumel	Gijsbert Houtman	Michael Haimerl	Hugo Bonnafous	Gijsbert Houtman	Michael Haimerl	Hugo Bonnafous	Gijsbert Houtman	Michael Haimerl

4.6 Change Management

‘Perform Change Control is the process of reviewing all change requests, approving the changes and managing them to adjustments in the deliverables, the organization, the documents and the project management plan.’ (Varsani, 2017)

As all the project members knew the action plan, the following steps had to be done, if one of them would have recognized any necessary changes in the project work:

- Information to the team and especially to the project manager
- If it is an important change, the team will set up an urgency meeting (in special cases together with the supervisor Niklas Frände)
- The team will discuss about the questions ‘What has changed?’, ‘Why has it changed?’ and ‘How do we deal with this change?’

The project manager will always remind the team to think about the project management triangle during their discussions and the solution finding. This triangle is shown below as Figure 19 and is only an exemplary presentation to visualize the effects of every decision.

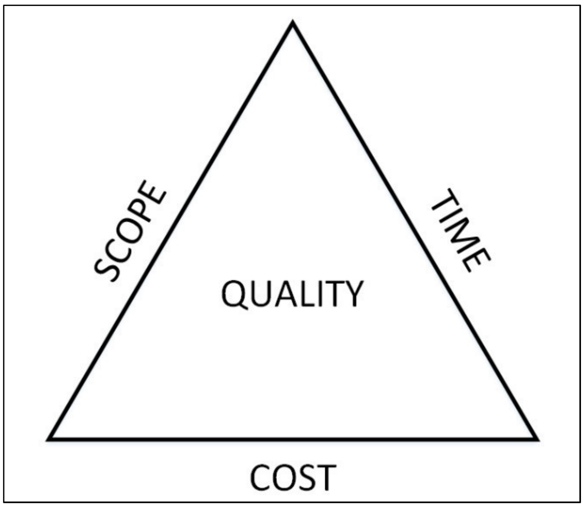


Figure 19: Project management triangle

Every change has influence on the scope, the time or the costs. Often, the word ‘quality’ is written in the middle of the triangle, because this should be the main concern of every change in the project. In case of this project, the time is the duration of 16 weeks or until the 18th of December. The scope is the work-breakdown structure and the costs are not determined, because it is a student project, but the working time of the team members can be compared by the costs. This helps to find suitable solutions for changes.

5 Project Execution

5.1 Grain for the livestock – short information & storing techniques

Various storing techniques and measures to preserve grain can be found around the world. This chapter focusses on techniques relevant for the project region, which are the storage in silos and the storage of wet grain in protective plastic packages. But why is grain used to feed animals? The next text passage gives a short introduction into this field of knowledge.

5.1.1 Food for the livestock and why there is a need of grain as food

The farmer's choice on what to feed their livestock depends on many factors. Some examples therefore are:

'What is the main value of the animals?'
'Is the intended livestock for meat, milk or egg production?'
'What is the expected performance range of, for example a cow?'

A high variety of ingredients can be feed to the livestock, but the animals performing at its best, will depend on the proper food the farmer gives to them. The farmer needs adequate knowledge about the livestock, the food and the amount of food he will feed. A classification of the food for the livestock is shown in the following table.

Table 7: Classification of animal feed

Name	**Green Fodder**	**Coarse Fodder** (also roughage)	**Concentrated Feed**	**Others** (e.g. molasses, mineral feed)
Description	freshly harvested food, which is directly feeded to the livestock	food with a high concentration of structured raw fiber; raw fibers are good for the digestive system of ruminant animals	high-energy food because of carbohydrates, starches and proteins; without or with a low concentration of structured raw fiber	*molasses* with a high concentration of sugar; *mineral feed* with a high amount of vitamins and mineral substances
Examples	pasture grass	grain chaff, straw also bulky food, e.g. beets, corncob	grain (barley, wheat, rye, oat), corn grains also **wet grain**	*molasses* by-product of sugar beets; *mineral feed* calcium, magnesium, iron, zinc

Grain contains a huge amount of starches and a significant percentage of raw proteins. A short description of the most important substances can be looked up in the appendix. The high-energy content of grain is a big advantage in contrast to pasture grass. Grain allows the farmers to reach their aspired goals of a high milk output of their cows or the fast fattening of the oxen. But the farmers must feed a mixture of coarse fodder and concentrated feed to their livestock, because the animals need also food with a high concentration of raw fiber for their health. The crimped grain contains a higher amount of raw fiber because of the grain chaff which is not separated in the crimping process. But it can be that additional coarse fodder is necessary. Nevertheless, feeding of grain to the livestock is the basis for a competitive agriculture sector.

5.1.2 Traditional grain storage with drying and storing it in silos

The most common storage technique is the loading of dried grain in silos. The following chapter shows the development of this measure, technical information and a conclusion with advantages and disadvantages of this technique.

5.1.2.1 History

As in the early 20th century grain production developed, a new technique for storing remaining grain was invented. During this time the first grain storage units, so called ‘grain elevators’, entered the market. The wooden buildings became very popular at mass production farms in Canada and the United States. Though those have not been weather-resistant, concrete silos were designed and build. This was the beginning of the steel silos, which are used nowadays.

Figure 20: Former way of grain storage in a ‘grain-elevator’ ©museeheritage.ca

5.1.2.2 The need of drying grain

Currently the most commonly way of storing grain is still in silos. But before the grain can be filled into the silos, it is important to get the seed dried. Getting moisture out of the grain prevents mold in the silos.

Figure 21: Grain storage in silos © Museeheritage.ca

Therefore, the humidity level of the grain must be decreased from 24-30% to 8-15% depending on type of grain and storage time.

This technique is very simple as the farmer only needs to make a one-time investment in drying machine and silos, but can make use of this capital investment almost unlimited and for various types of grain that can be stored inside of the silos.

5.1.2.3 Status and Success of this technique

Silos are only used on farms, that have the right capacity to store. Which means on farms that have sufficient livestock to feed and produce enough grain to fill the silos. By using continuous flow dryers in the silo, the farmer can preserve the grain for a longer period. The technique is a safe way to store the grain, and there is only a small chance that the grain gets damaged. On top of that the farmers using this drying and storing technique have a few more benefits, just as being able to trade the grain to other farmers.

Drying and storing grain in silos brings several advantages and disadvantage that can be seen in the following Table 8.

Table 8: Advantages/Disadvantages of grain storage in silos

Advantage (+)	Disadvantage (-)
One-time investment, resale-able	Drying costs, energy and required machines
Reliable and safe technique for grain storage	Silos need to be cleaned
Easy grain unloading	Location of silos is fixed
Grain can be traded between farmers	

5.1.3 Wet Grain in Tubes

In the 1950's, a German manufacturer of agricultural machines developed the storage of wet grain in big plastic tubes. Over the last decades, several other manufacturers and producers of plastic foils developed and enhanced own packaging machineries and foils. This chapter gives a short introduction in the processes of wet grain packaging and a conclusion with advantages and disadvantages.

5.1.3.1 History

While the most common storage technique are the silos, not all farmers are capable to invest their money into those silos. For these farms that are too small and harvest to little, 'big tubes' where invented. Big tubes offer a low capital investment solution, with cheap material for the bags and low harvesting costs.

Figure 22: Wet grain tubes © Wis

5.1.3.2 Technology in Detail

To explain more about the current technology which the farmers use to fill the big tubes, team 'Korntainer' visited a little farm just outside Vasa. The farmer which the team visited is using the techniques which other farmers are using in Norway, Sweden and Finland. But the farmers around Vasa do not have the right equipment and machinery to fill the big tubes. That's why an entrepreneur goes to every little farm in Vasa and provides the farmers with the right equipment and machinery to fill the bag.

The farmer and entrepreneur start with positioning the big tube. Typically, close to the livestock where the farmer wants it to be positioned. This will provide low costs by short transportation ways. When the farmer chooses the right position to fill the big tube, the farmer makes a fundament of sand, the fundament of sand to avoid that any sharp stones can damage the big tube.

Figure 23: Technique to fill the big tubes

The grain will be filled in the machine and crimped inside. The crimping technique is nothing else than breaking the shell of the grain and make smaller parts of grain. After the machine crimped the grain, it will add a mix of water and weak acids. The mix of water and weak acids preserve the grain for a longer period.

The difference between the grain before and after crimping can be seen below:

Figure 24: Grain before crimping

Figure 25: Grain after crimping

The grain will be stored in the big tubes. When the machine fills these tubes, it will put a lot of pressure on the wet grain inside to avoid any air bubbles. The big tubes can grow between 40 meters and 90 meters, and have 2,7 meters in diameter. The farmer must cut the bag open to feed the livestock. A big disadvantage here is that the big tube cannot be closed after is cut open. The grain on the surface will dry out and cannot be used for feeding the livestock.

Figure 26: End result grain tube

5.1.3.3 Status and Success of this technique

A lot of farmers are using the crimping technique and store the grain in big tubes. For a small farm, it's a cheap way to store the grain. The farmer only must pay for the material costs of the big tube and pay the entrepreneur with is equipment and machinery. But there are also a few disadvantages. When the farmer has a higher harvest production than necessary for feeding the livestock, the farmer is not able to trade the left over because of the current storage technique. But the biggest problem of the current technique is the plastic waste. Most of the farmers are giving the plastic waste to a landfill or to a waste incineration plant, which are the two worst options for the environment.

The advantages and disadvantages of this storage technique are summarized in the following Table 9.

Table 9: Advantages/Disadvantages of Wet Grain in Tubes

Advantage (+)	Disadvantage (-)
Flexible storage locations	No trading possible
Cheap material	Transportation not possible
Storage of wet grain	Plastic waste after use
Able to contain weak acids	Not closable after first time use
Several storage possibilities	Easily damageable
	Feed waste after exposure

5.1.4 Economical comparison of the two grain storing techniques

The greatest advantage of the wet grain storing technique is the missing drying process. Such a procedure requires a lot of energy and equipment. Both things cost a significant amount of money. The following comparison of dry grain storage and wet grain storage is based on a calculation of the manufacturer 'ROmiLL'. The company has its headquarters in the Czech Republic and develops agricultural machines and technology to produce feed. For further information visit the website. (www.romill.cz/en)

Table 10: Economical comparison of dry grain storage and wet grain in tubes ©ROmiLL

	Drying of harvested grain with 35% moisture content	**Drying of harvested grain with 28% moisture content**	**Crumbling of wet grain with 30-40% moisture content**
Quantity of maize grain harvested from 100 ha	1.000 t	1.000 t	1.000 t
Harvest by a picking thresher	7.000 €	7.000 €	7.000 €
Crumbling using ROmiLL M2 (wet grain crimping & storing machine)			**6.000 €**
Preservatives + covering foils (wet grain crimping & storing process)			**4.300 €**
Transportation from the field to a trough			2.310 €
Transportation from the field to a drying plant	2.310 €	2.310 €	-
Drying maize to 14% moisture content	27.300 €	18.200 €	-
Transportation from the drying plant to a silo	2.310 €	2.310 €	-
Grinding of dry grain	1.000 €	1.000 €	-
Costs of the storage of dry grain	Not calculated	Not calculated	-
Costs of one-ton harvest	**40 €**	**31 €**	**20 €**
Total costs per 1.000 t (approx. 100 ha)	**39.920 €**	**30.810 €**	**19.610 €**

The data is valid for harvesting and storing maize grain in the Czech Republic in the year 2004. Although these are not the latest figures and the calculation is made by a manufacturer of wet grain storing machines, the advantages of the storage of wet grain in big tubes can be seen. 'ROmiLL' examined a difference of 20 € per Kilogram or 20.310 € for 1.000 tons of harvested grain between the traditional storing technique and the wet grain storage. Beside of the lower process costs, the wet grain storage does not require dry circumstances on the field for the harvesting process. This is a big advantage for the farms in the project region of Ostrobothnia with its wet and fast changing climate.

The only big disadvantage of the wet grain storage is the huge amount of plastic waste.

5.2 Wet Grain in Packages – Development of a new technology

'*The project develops an energy saving, cost and environmentally effective system to pack, store and manage crimped grain at high water content to increase the profitability of grain cultivation in the program area'* [1]

This new idea of the small grain packages aims for the trade market of grain with an eco-friendly and cost saving method.

5.2.1 Business need and Idea

The idea behind the relatively small grain packages is that they can be transported and traded. This is a big advantage for the product, where farmers, who do not produce enough grain for their land, can buy these grain packages on the market and farmers who have a surplus of harvested grain can store it in the grain package and sell it.

Marketing models for the product are being made by Mikael Ehrs. The study will show if there is a market for trading the grain packages and in which of the three countries of the project the system will be profitable.

5.2.2 Short description of the packaging technique

The crimping technique is the same as the farmers are using for the big tubes, only this time the bags are more compact. The new technique makes it possible to trade the grain bag between the farmers. The farmers can buy grain bags or sell them when there is a larger amount of harvest than necessary. For more information, see 5.1.3 'Wet Grain in Tubes' and the website www.botnia-atlantica.eu.

5.2.3 The new storage units in Detail

For this sub-project the material and the shape of the packaging of the wet grain are the two things, which are of interest and not the packaging technique and process. Therefore, the following chapters describe the requirements for the storage units in general and presents the design development with a conclusion, which is the basis for the further considerations regarding the final design of the storage units.

[1] Source: European regional developing fond

5.2.3.1 Requirements in general

Considering the idea of the wet grain package and analyzing the environmental factors in the project region, the following requirements for the product are recommended:

- The package needs to contain weak acids (PH 4-7).
- The package needs to be able to be transported easily for trading.
- The package needs to be able to contain 1m^3 of wet grain.
- The package needs to be eco-friendly.
- The package needs to have an end of life potential.
- The package can be stored in a wet environment.
- The package can be stored in sunlight.
- The package can be stored in the snow
- The package can be stored in min. -10° Celsius conditions.
- The package can be stored in max. 40° Celsius conditions.

5.2.3.2 Design options

There were no concrete guidelines or suggestions how the new bags should look like. But it was clear that the new bags should be no special constructions, but standard industrial products. On basis of these consideration, the project team examined two possible designs, which should always follow a cubical shape. Figure 27 below shows these two options.

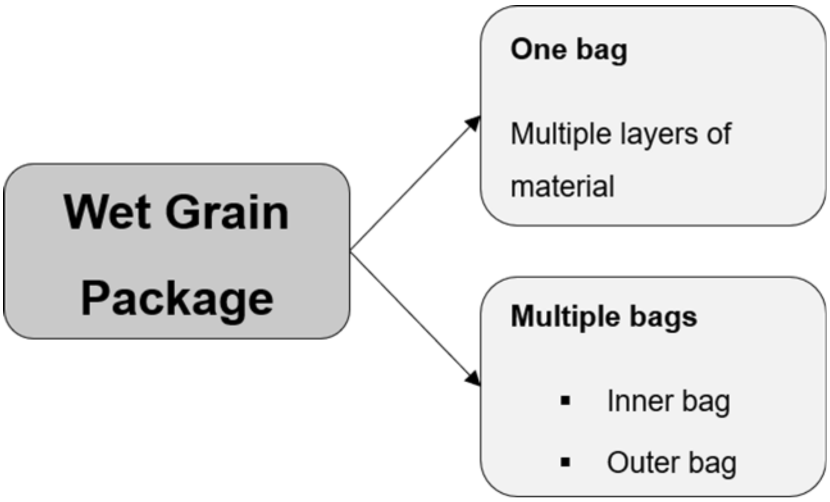


Figure 27: Design options for the new storage units

These two options are analyzed regarding their suitability for the new storage units by summarizing their advantages and disadvantages:

- **One bag option**

There are multiple design options for the grain package, where making one bag is the easiest option because it would be just one product. The problem with using one bag for the grain is that there might be multiple layers of various materials.

Just like the grain tubes nowadays, the grain package needs to be protected against UV radiation, but also be able to be outside in the sunlight. The grain tube has three layers of plastic, one black colored layer inside to keep the UV radiation out, and two white layers to reflect the sunlight and prevent the tube from getting hot. Using these multiple colored layers will make it impossible to sort the plastic waste of the bag color by color, which diminishes the recycling value.

The end of life potential for the one bag option is also low as the bag cannot be reused because the inside of the bag is too dirty, and washing it will not get rid of all the left-over grain. Table 11 summarizes the advantages and disadvantages of the 'one bag' option.

Table 11: Advantages/Disadvantages of a 'one bag' option

Advantages (+)	Disadvantages (-)
One product	Using multiple layers
Easy to use	Difficult to manufacture
	Hard to recycle
	No reuse option

- **Multiple bags**

Producing the grain package out of two bags, an inner and an outer bag, makes it easier to use two materials which have the best properties for their requirements. For example, the inner bag does not have to be strong enough for the weight of the grain when it is inside a strong enough outer bag. This is also a material saving option.

With a black inner bag and a white outer bag, the package will still reach the requirements. It is even an option to use a product that is already on the market as outer bag, for example the big bags.

Table 12: Advantages/Disadvantages of a 'Multiple bags' option

Advantages (+)	Disadvantages (-)
Cheaper	Two products
Make use of more materials	
Easy to separate the different materials	
High end of life potential	
Reuse is an option for the outer bag	
Save material for the inner bag	
Using existing product	

5.2.3.3 Conclusion regarding the most suitable storage unit option

Regarding the advantages and disadvantages of both, the ‘one bag’ and the ‘multiple bags’ option, the project team determined that the idea of two bags is the most suitable option for the project. This decision was done in consultation with the supervisor, Mister Niklas Frände. Figure 28 and Figure 29 show the basic idea with two examples of each a future outer bag and an inner bag.

Figure 28: Big bag as an outer bag ©*CES-EduPack*

Figure 29: Thin foil as an inner bag ©*CES-EduPack*

5.2.4 Short description of the tool 'Table of requirements'

A table of requirements is a design process where the requirements and design wishes of a product are listed. Using this method creates a clear table of measurable requirements for a product. The requirements are divided in four groups:

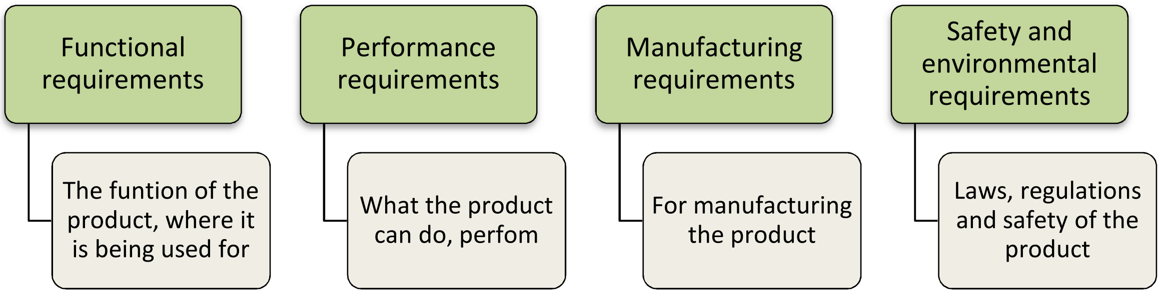


Figure 30: Presentation of the main groups of a table of requirements

A table of requirements defines the basis of the design, gives a direction towards a solution, improves teamwork and sets restrictions for a project. As an additional group of requirements, 'wishes' can be added to the list. These requirements describe things, which are good to have or to realize, but which are not necessary for the product.

5.2.5 Presentation of the tool for the search of suitable plastics

CES-EduPack 2017™ is used for searching and choosing the right material for the grain package. This tool contains a complete database of all commercial available plastics and its properties.

Figure 31: Logo ©CES-EduPack

Benefits of the program:

- Reliable and up-to-date data (2017)
- Supports sustainable design
- Eco-audit function for show environmental pollution
- Useful search parameters

5.2.6 Determination of the right search parameters

The program CES-EduPack gives comprehensive information about suitable materials automatically. However, this process requires the right search parameters.

- **Material universe**: *all polymers*

At first, the 'Material universe' needs to be chosen. Almost all common plastics are polymers, what means that they consist of repeated subunits, which have no clear structure when viewed under a microscope. This parameter helps to narrow the search in a first instance.

- **Processing properties**: Polymer extrusion: *excellent*

A further important parameter is the 'Processing properties'. Products, like bags, are mainly made by extrusion. This is a cheap and efficient production method, which also allows lower material thicknesses. CES-EduPack divides materials for this process by four categories, which are shown in Table 13.

Table 13: Categories of materials for the extrusion process by CES-EduPack

Rating	Meaning
Excellent	The material is frequently used for extrusion and does not present any major problems.
Acceptable	The material is generally used, but may not be an optimized grade.
Limited use	The material may be used in limited cases, or requires additional measures to avoid problems.
Unsuitable	The material is not used for extrusion.

In the case of this sub-project, materials with an extrusion level of 'Excellent' are recommended.

- **Durability**:
  - Water (fresh): excellent
  - Water (salt): excellent
  - Weak acids: excellent

The new technique of the transnational project 'Wet Grain in Package' is based on the same technology as it is used in the storage of grain with big tubes. The grain is still wet, because it does not need to be dried before. To preserve the grain for a long time, a weak acid is added (PH 4-7). That is why the material of the inner bag needs to be excellent against weak acids. CES-EduPack uses a four-point scale to categorize materials and their resistance against liquids, for example 'water (fresh)', 'water (salt)' and 'weak acids'.

Table 14: Categories regarding the level of resistance against various liquids

Rating	Meaning
Unacceptable	Do not use it in an unprotected condition.
Limited use	Not recommended, although may be suitable for short term applications.
Acceptable	May require additional protection.
Excellent	No degradation in material performance expected after long term exposure.

It is recommended, that materials with an 'Excellent' grade of protection against fresh water, salt water and weak acids are searched.

- **Recycling and end of life**:
  - Recycle: yes
  - Downcycle: yes
  - Landfill: yes

This parameter indicates, for example, whether a material can be safely deposited in a landfill site or not. This is one of the six main options the program CES-EduPack knows for handling materials at the end of a product's life. The relative environmental impact of these options is summarized in the Table 15.

Table 15: End of Life options, their description and their environmental burden

End of Life option	Description	Environmental burden
Reuse	Extension of product life	*Lowest*
Re-engineer	Incorporation of re-engineered part into new product	↕
Recycle	Reprocessing of material into primary supply chain	
Downcycle	Reprocessing into a lower grade material	
Combustion	Recovery of the calorific content of the material	
Landfill	Disposal of material	*Highest*

It is recommended to search for materials which offer at least a safe deposit of them in a landfill site and even more important an option to 'recycle' or 'downcycle' the material.

5.2.7 Wet grain in packages – Development of the 'outer foil'

This chapter informs about the development path of the 'outer foil'. It contains the table of requirements, a research of suitable materials with a conclusion, an overview of similar products in the industry and the development of possible designs of the outer bags.

5.2.7.1 Table of requirements 'Outer bag'

The outer foil needs to fulfil several requirements, which are listed in Table 16 and Table 17. These requirements are the result of the research work and the meetings with the supervisor Niklas Frände and are based on the thoughts of the chapter 'Requirements in general'. A detailed description of the requirements can be looked up in the appendix.

Table 16: High-level list of the requirements of the outer foil or big bag – section 1

Performance requirements (PR)	
1PR	The outer bag must protect the inner bag.
2PR	The outer bag needs to be transportable.
3PR	The material of the bag has a durability for 4 or 5-time use.
4PR	The outer bag has a volume of 1 cubic meters. (LxWXH) 100x100x100 cm.
5PR	When the outer bag is not being used it has to be stored in an efficient way.
6PR	The logo of the company can be printed on the material of the outer bag.
Functional requirements (FR)	
1FR	The characteristics of the material of the outer bag need to be strong.
2FR	The outer bag must carry a weight of a maximum of 1500 kg. when it got lifted from the ground.
3FR	The outer bag has features that opens and close the outer bag.
4FR	The outer bag has the same stretch as the inner bag.
5FR	The outer bag can get materials attached to the outer bag.

The 'Performance requirements' and the 'Functional requirements' of Table 16 can be summarized as a one cubic meter bag with transport loops, which is robust and strong enough to carry the inner bag with the wet grain.

Table 17 gives a closer look on the manufacturing process, the safety and environment requirements and the wishes the project team had for this product.

Table 17: High-level list of the requirements of the outer foil or big bag – section 2

Manufacturing requirements (MR)	
1MR	The material of the bag has to be made by machines, and in an efficient process.
Safety and environment requirements (SR)	
1SR	The loops attached to the outer bag needs to be secure.
2SR	The material of the outer bag needs to be produced with as little carbon dioxide emissions as possible.
Wishes (W)	
1W	After the material no longer meets the requirements, it must be biodegradable.
2W	After the material no longer meets the requirements, it must be recyclable.

These requirements can be summarized as a bag, which can be produced in an industrial way to save production costs with a material that does not cause greater carbon dioxide emissions. The attached loops need to be safe to guarantee a secure handling. In the best case, the material is biodegradable or if this is not possible, it should be at least recyclable after its lifecycle.

5.2.7.2 Possible materials

For choosing the material of the outer bag the following requirements of the table of requirements are important:

- The outer bag needs to be able to contain 1m^3 of grain that is filled into the inner bag
- The outer bag needs to be strong enough for the weight of the grain
- The outer bag can be transported by a tractor with a forklifting unit
- The outer bag can be reused
- A zip or rope/string can be attached to the outer bag
- The name of the company can be printed on it

To find a usable material, the program CES EduPack is being used and the main parameters for the search of suitable materials were being selected. These parameters have already been defined in 'Determination of the right search parameters'. A new parameter can be found in the processing properties. Beside of the polymer extrusion is also a polymer injection molding possible. This is caused by a short research about production processes in the plastic industry, which showed that the injection molding is used for various plastics. Therefore, the team decided to search for materials with this characteristic.

- **Material universe**: all polymers
- **Processing properties**:
  - Polymer extrusion: excellent
  - Polymer injection molding: excellent
- **Durability**:
  - Water (fresh): excellent
  - Water (salt): excellent
  - Weak acids: excellent
- **Recycling and end of life**:
  - Recycle: yes
  - Downcycle: yes
  - Landfill: yes

By using these research parameters, the material data bank of CES EduPack examined the following suitable materials:

- **ABS** Acrylonitrile butadiene styrene
- **I** Ionomer
- **PC** Polycarbonate
- **PEEK** Polyetheretherketone
- **PE** Polyethylene
- **PP** Polypropylene
- **PS** Polystyrene
- **PTFE** Polytetrafluoroethylene
- **PVC** Polyvinylchloride

It is important to compare these polymers on the following two levels:

- **Price** (EUR/kg)
- **Density** (kg/m^3)

Price related to density is an important criterion. The bag needs to be as cheap as possible, and have a minimum weight. These two criteria allow a comparison of various plastics, because a comparison of only the prices per kilogram for plastics, whose densities are different and so the weight of the product, would be wrong.

The following diagram of CES EduPack shows this relation of density and price per kilogram for the examined suitable plastics.

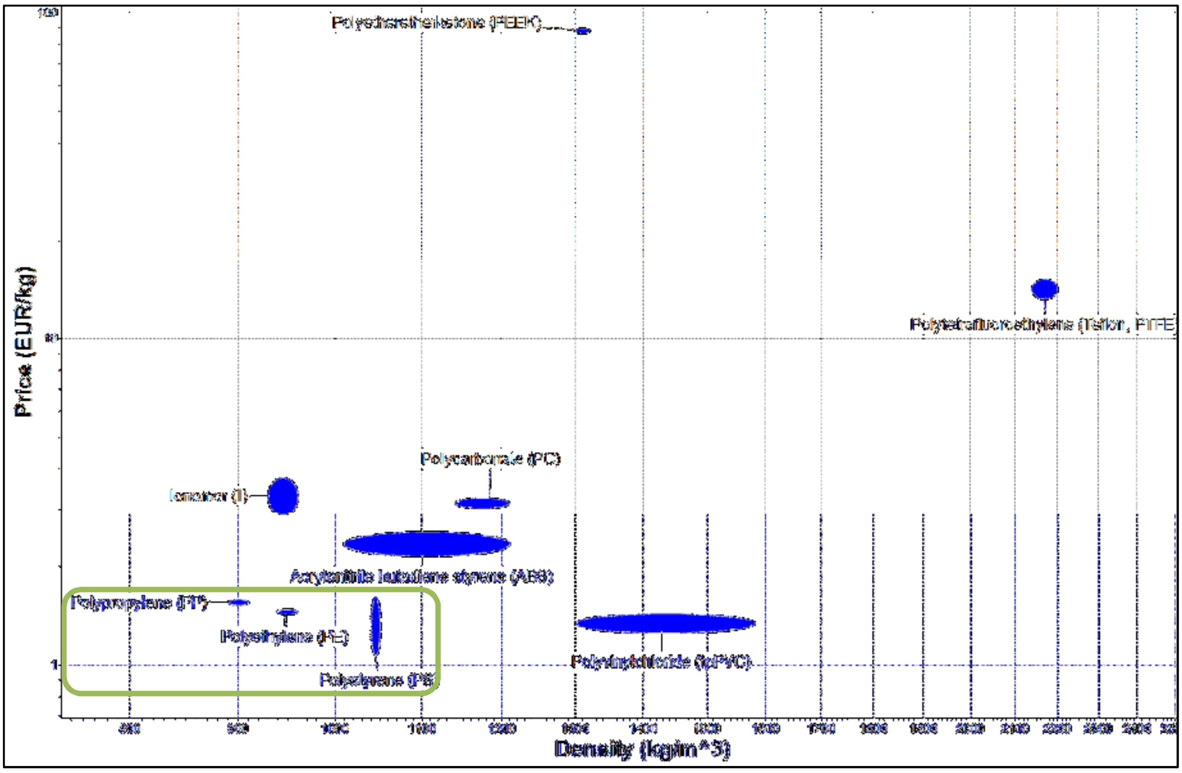


Figure 32: Comparison of selected plastics by their density & price per kilogram (outer bag)

As one can see in Figure 32, a lot of polymers are not useful for the outer-bag because of their high price, their density or a combination of both. For example, PTFE or Polytetrafluoroethylene and PEEK or Polyetheretherketone cost too much or have a high density. A bigger group of various plastics can be found in a range of 1 to 8 Euros per kilogram and a density of 800 to 1600 kilogram per Cubic meter. Since one of the objectives of this project is to find a material, which is not too expensive, the project group recommends focusing on three plastics. They are highlighted in green in the diagram and listed below:

- **PE** Polyethylene
- **PP** Polypropylene
- **PS** Polystyrene

A research showed that these plastics are also the most common materials in many areas of the industries, different businesses and in the daily life. The following table gives a short description of the most important characteristics of the three plastics. It shows pictures of the most common products out of each plastic, more possible areas of application, some technical facts and at the end a conclusion if the plastic is suitable for the outer bag or not.

Table 18: Characteristics of the selected plastics – outer bag

	Polyethylene (PE)	Polypropylene (PP)	Polystyrene (PS)
Materials			
Typical uses	Food packaging, plastic bags, oil container, shrink wrap, wet grain tubes	Big-bags, garden furniture, car bumpers, suitcases, crates, pipes, ropes	Toys, mirrors, lenses, beakers, cutlery, video/audio cassette cases, pens.
Technical notes	Different polyethylene materials, PE-LD (low density polyethylene) used for packaging and film, PE-MD (medium density polyethylene) and PE-HD (high density polyethylene) are stiffer, stronger and used for containers and pipes.	The properties of PP are similar with PE-HD but PP is stiffer and more though. It is inexpensive and a light material.	Cheap polymer but very brittle, it breaks easily. The mechanical loading is light, there is not much polystyrene used in large products.
Useful for outer bag?	No, not strong enough	Yes, excellent	No, too brittle

The table shows that Polystyrene is not suitable for the big bags at all, because it is not durable enough. Polyethylene is also not recommended. The material itself is too weak to carry the weight of the wet grain and a high effort is needed to design or weave a bag out of it that is durable enough for the weight. Polypropylene is the best material for the outer bag. Because the outer bag needs to protect the inner bag, this strong and stiff material is very useful.

The outer bag can be used several times and in addition, the bags out of Polypropylene can be recycled. Because big bags out of Polypropylene are very common in industry, there is an efficient production of the bags and the companies have an established recycle process for this product. The target of this project to find an environmentally friendly material for the outer bag is achieved.

5.2.7.3 Comparison with common techniques and products

The results of the program CES-EduPack and the recommended material Polypropylene need to be verified by a comparison with the industrial practice. There are a lot of companies which are producing or using ‘big bags’. The research followed some specific questions:

- What is the main purpose of the big bags?
- What material are the companies using?
- How are the bags produced?
- Is the main material recyclable?

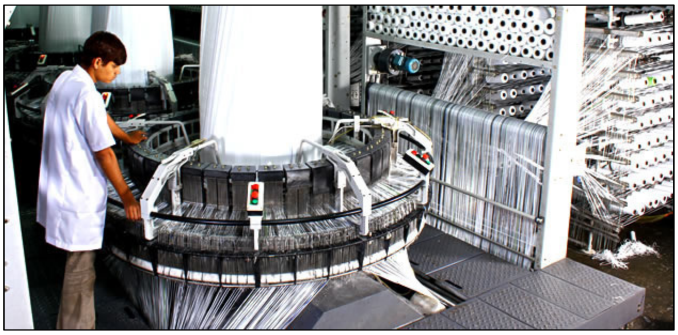


Figure 33: Production outer bag © Comsyn

Most of the time, the users apply the big bags for transportation and storage of all types of materials. The bags can be used to fill in sand, chemicals, food or production waste. The most used material for the big bags is ‘Polypropylene’. The producer applies a second layer of material when the first layer is not sufficiently able to protect the product. When the bags are filled with chemicals or food, most companies use a second layer of ‘Polyethylene liners’. These ‘Polyethylene liners’ give protection against moisture. (Comsyn, 2017)

The bags are made by machines. These machines are supplied with big rolls of ‘Polypropylene’ fiber strings. These long strings are woven together, as one can see in Figure 33. The woven fibers have a tubular shape and guarantee the durability of the bag and their resistance against damages. It is the most common technique used for producing the bags. The producer can change the strength of the bag by using various thicknesses of fibers. The more fibers the company use, the more the strength and weight of the bag will be increased. (Agrosak, 2017)

The research showed that the recommended material Polypropylene is a common product in industry, what facilitates the implementation of the outer bag because it is possible to get the outer bags on the market.

5.2.7.4 Morphological Charter

A morphological charter is used as an instrument to find solutions for problems in the development of a product or to create new ideas in general. In the following case, this tool is used to collect designs of the new packaging for the wet grain storage units. The considered options are based on the five viewing points 'Transportation', 'Closing Feature', 'Protection Material', 'Recyclable Material' and 'Biodegradable Material'. The 'Transportation', the 'Closing Feature' and the 'Protection Material' are parts of the functional design of the new bags, whereas the 'Recyclable Material' and the 'Biodegradable Material' look at the future possibilities for the product after its usage.

Table 19: Morphological Charter

Function	Option 1	Option 2	Option 3	Option 4	Option 5
Transportation	*Loops*	*Pallets*	*Wheels*	*Rails*	-
Closing Feature	*Zip*	*Buttons*	*Velcro Strap*	*Rope*	-
Protection Material	*Wood*	*Plastic*	*Stone*	*Metal*	*Glass*
Recyclable Material	*Wood*	*Plastic*	*Stone*	*Metal*	*Glass*
Biodegradable Material	*Wood*	*Plastic*	*Stone*	*Metal*	*Glass*
→	Option 1	→	Option 3	→	Option 5
→	Option 2	→	Option 4		

Option 1

Using the loops for transporting the bag is the most common way for the farmers. The farmers use a tractor with a forklifting feature to put the bags on a trailer and bring several bags to the shelter. The outer bag must protect the inner bag and for this purpose plastic is used. Plastic has a major benefit because it is very light weight but there are some possibilities to make the plastic stronger. Also, plastic is very stretchable. There are a few plastic materials in a group called elastomers which are recyclable or biodegradable. A common closing feature for bags is a zip which is a very easy and safe way to close the bags. Even when there is a lot of tension on it, it will not open by itself or by the weight of the bag.

Option 2

Putting bags on a pallet, makes it easier to transport them. The pallets with the bags can be easily lifted on a trailer by using a forklift of a tractor. The bags can be closed by buttons, which is an easy click system to open and close the bags. There is only one major disadvantage to the closing feature at the bottom of the bag. When the farmer wants to empty the bag, the full weight of the bag leans on the buttons. So, there is a possibility that the buttons cannot hold the weight of the bag and the inner bag would fall out of the outer bag. The material, that protects the inner bag, is made of wood. This material is biodegradable and in addition, gives the possibility to recycle the bag or box. Nevertheless, the disadvantage is the required amount of space for the wood boxes, which must be stored somewhere after their usage.

Option 3

There are wheels under the bags, for transporting them more easily. With this the farmer can make a long train by attaching the bags to each other and then transport these bags behind a tractor and store them in a shelter. A disadvantage for this way is that the farmer cannot store the bags properly, because the inner bag is protected by an outer bag made of stone. A further disadvantage is the weight of the bags, which makes it impossible to transport them properly. Also, there is not a possibility to put a closing feature in the bag or box. An advantage for using stones is the possibility to reuse the stones for something else.

Option 4

To transport boxes made from metal, rails should be used. The farmer would need a rail track from his land to the shelter. This gives him the opportunity to put the bags on a sort of train and then transport a huge amount of them easily to his shelter. However, this is not a very attractive choose. The farmer must install an own track, what will cost a lot of money. The closing feature can be made of a rope system. This system is very difficult to use on a metal box. Otherwise, the metal, that is used for the boxes, can be reused for something else. For this reason, there are some recycle possibilities.

Option 5

This option is almost the same as option 1. The materials and the transportation system are the same, only the closing feature is different. Instead of a zip, the farmers will use a rope or string as a closing feature. These strings are attached to a filling tube. After the bags are filled, the farmer will use a string to close the tube to prevent the grain from falling out of the bag. (For further information, see chapter 'Closing feature idea for the outer bag').

5.2.7.5 Conclusion morphological charter

After discussing the different options, team 'Korntainer' can give recommendations for creating the outer bag. The team will not give a specific solution because the most suitable one depends on the machine that will fill the bags. The best recommendations are option 1 and option 5. The material of the outer bag and the transportation system are the same, but the farmer can choose the closing feature, but he will also choose the bag that is the most comfortable one to use. The chapter 'Closing feature idea for the outer bag' gives a closer look on these closing mechanisms of the bags.

Characteristics of the outer bag.

- Material: Plastic, can be woven
- Closing feature: Zip or rope (string)
- Transportation system: Loops

5.2.7.6 Design options

Team 'Korntainer' examined four possible designs of the big bag. As the team did not have any further information about the new developed packaging machinery, the development of the designs had not to follow any regulations or requirements of the packaging process. The descriptions of the following options only follow the aspect of the packaging process on a farm in general.

The first idea is putting the closing feature at the edges of the bag. Figure 34 shows where the closing features are placed. The closing feature is a zip without any interruptions. For filling the bag, the farmer opens the zip, and closes it after the bag has been filled. The only difficult part is the emptying of the bag, because the farmer must push the bag on the side, so he can take the grain out of the bag. By using this technique, the outer bag can be damaged. It is possible to put more loops on the outer bag. With more loops on the bag, the farmer can turn the bag until the zip is on the bottom. The inner bag could be cut open by a mechanism or manually.

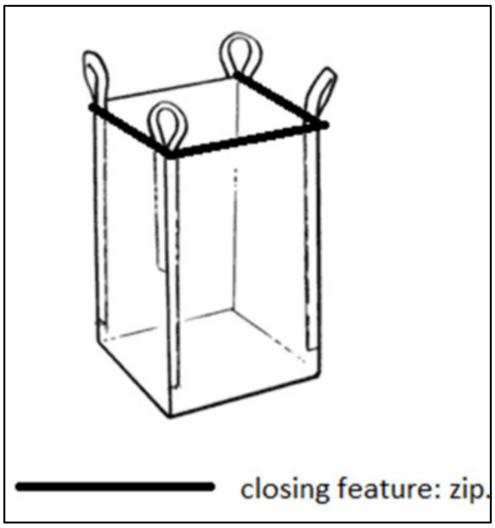


Figure 34: Outer bag with zip as closing feature © Bigbagstrading.

The second idea is almost the same as the first idea, but this time the closing feature is placed in the middle of the lid's surface. The farmer can fill the bag by opening the zip, and close the bag when the bag has been filled. This bag has the same problem as the first idea and it can be solved in the same way by attaching more loops to the other edges of the bag. One advantage is the higher security, because if the farmer opens the zip, the inner bag will not fall out of the outer bag. Another advantage is the possibility of closing the bag again and storing a part of the grain, if not everything is used.

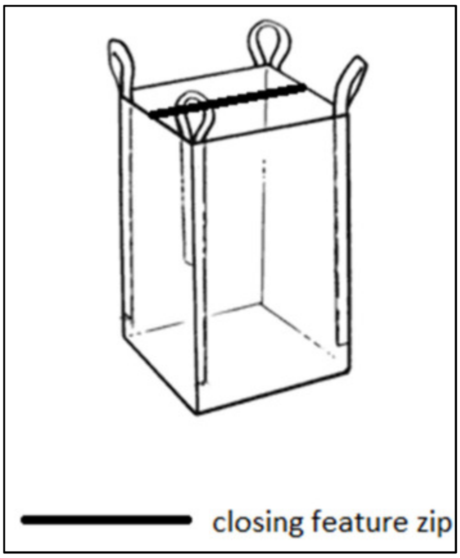


Figure 35: Outer bag with zip as closing feature ©Bigbagstrading

The third idea is an outer bag with a filling tube. The tube is an easy way to fill the bag. By using a rope or string, the farmer can close the filling tube. This outer bag is only feasible in the case that the filling machine can flip the bag after it has been filled. When the loops are on the top, it will be easy to transport the big bag. When the farmer wants to empty the bag, the bag is already in the right position. The farmer needs to pick up the bag and loose the rope or string. The grain goes through the filling tube and will end up in a mix machine. After using the bag, the farmer can easily clean the bag and store it.

Figure 36: Outer bag with filling tube ©Westfalia

Idea four is quite similar with idea number three. But this idea has two filling tubes. This is probably the easiest system to use. The farmer fills the bag by using the filling tube on the top. The bottom tube can be closed by a rope or string. With the two filling tubes, the filling machine does not need to flip the bag. After filling the bag, the farmer closes the tube by a rope or string. When the farmer wants to empty the bag, he only needs to lift the bag and loose the rope or string. The grain goes through the filling tube and will end up in a mix machine. After using the bag, the farmer can easily clean the bag and store it like in the case of idea number three.

Figure 37: Outer bag with filling tubes © 123bigbags

At the end, the type of bag depends on how the filling machine is operating and if the bag can be flipped or not. Also, the economic side of the bag is very important. As the feasibility study of the project management phase has shown, the agricultural sector in Finland cannot use any expensive materials or extras, like special closing features. These thoughts will be considered in the evaluation of the investigated solutions at the end of the report.

5.2.8 Wet Grain in Packages – Development of the 'Inner foil'

This chapter informs about the development path of the 'inner foil' and has a similar structure as the chapter about the 'Development of the inner foil'. It contains the table of requirements, a research of suitable materials with a conclusion and an overview of similar products in the industry.

5.2.8.1 Table of requirements 'Inner bag'

Like the outer foil, the inner foil needs to or should fulfil several requirements, which are listed in Table 20 and Table 21. These requirements were developed during several meetings with the supervisor Niklas Frände and these considerations are based on the results of the chapter 'Requirements in general'. More details to each requirement can be found in the appendix.

Table 20: High-level list of the requirements of the inner foil – section 1

Performance requirements (PR)	
1PR	The inner bag needs to be able to contain 1m³ of grain.
2PR	The inner bag needs to be strong enough for the weight of the grain.
3PR	The inner bag must contain weak acids (PH 4-7).
4PR	The material of the inner bag can be used for packaging food for the livestock.
5PR	The inner bag needs to be cheap because it is for one use.
Functional requirements (FR)	
1FR	The inner bag is stretchable.
2FR	The material of the inner bag is weak enough to cut open.
Manufacturing requirements (MR)	
1MR	The bag needs to be created by a machine with the lowest expenses as possible.

The section 'Performance requirements' characterizes the inner bag as resistant against weak acids. These acids are used to preserve the wet grain. In addition, the inner bag must be without toxins, cheap and strong enough to carry the weight of up to one cubic meter of wet grain. The 'Functional requirements' describe this term 'strong' more in detail. It means that the inner bag is stretchable. This is necessary, because in case of a hole between the layers of the outer and the inner bag, the grain would be carried alone by the inner bag. Therefore, the inner bag must be stretchable to adjust its own shape to close this hole and get in contact with the outer bag, which is able to carry the weight. As it is also mentioned in this section, the material of the inner layer should not be too strong, because it should be able to cut it easily. The 'Manufacturing requirements' recommends an efficient industrial production process with low costs to reach the goal of a cheap inner bag.

Table 21: High-level list of the requirements of the inner foil – section 2

Safety and environment requirements (SR)	
1SR	The bag must able to get recycled after use.
2SR	The material of the inner bag has to be produced with as little carbon dioxide emissions as possible.
Wishes (W)	
1W	The inner bag can be recycled in the same factory where they are created to a new inner bag.
2W	When the bag is empty it must take as little space as possible.
3W	The material of the inner bag can be welded together.
4W	The material of the inner bag is biodegradable.

Table 21 shows the requirements regarding the 'Safety and environment' and some 'Wishes'. The 'Safety and environment requirements' chapter only includes considerations for the environment, as for example a possible recycling aspect or the need of a production process with low carbon dioxide emissions. The list of 'Wishes' includes the search for the implementation of a regional recycling cycle, an efficient storing of used bags and a material, which is in the best-case 'biodegradable'.

5.2.8.2 Possible materials

For choosing the material of the inner-bag, the following requirements of the table of requirements are important:

- The inner bag needs to be able to contain 1m^3 of grain.
- The inner bag must be able to contain weak acids (PH 4-7).
- The bag must able to get recycled after use.

To find a usable material, the program CES EduPack is being used and the main parameters for the search of suitable materials were being selected. These parameters have already been defined in 'Determination of the right search parameters'.

- **Material universe**: all polymers
- **Processing properties**: Polymer extrusion: excellent
- **Durability**:
  - Water (fresh): excellent
  - Water (salt): excellent
  - Weak acids: excellent
- **Recycling and end of life**:
  - Recycle: yes
  - Downcycle: yes
  - Landfill: yes

By using these research parameters, the material data bank of CES EduPack examined the following suitable materials, which is the same selection as for the outer bag:

- **ABS** Acrylonitrile butadiene styrene
- **I** Ionomer
- **PC** Polycarbonate
- **PEEK** Polyetheretherketone
- **PE** Polyethylene
- **PP** Polypropylene
- **PS** Polystyrene
- **PTFE** Polytetrafluoroethylene
- **PVC** Polyvinylchloride

It is important to compare these polymers on four levels. For the final material selection, 'Price' and 'Density' are more important than the 'Embodied energy' and the 'CO_2 footprint'.

- **Price** (EUR/kg)
- **Density** (kg/m^3)
- **Embodied energy (primary production)**
- **CO_2 footprint (primary production)**

The relation 'Price to density' is an important thing. The bag needs to be as cheap as possible, and be of a minimum weight. These considerations led to the same material selection for the inner bag as for the outer bag.

- **PE** Polyethylene
- **PP** Polypropylene
- **PS** Polystyrene

Table 22 summarizes important technical notes of the materials. For the inner bag, Polyethylene (PE) is the most suitable material, because it is usable for food packaging and PE-LD (Polyethylene-low density) is also stretchable and strong enough.

Table 22: Characteristics of the selected plastics – inner bag

Materials	**Polyethylene (PE)**	**Polypropylene (PP)**	**Polystyrene (PS)**
Typical uses	Food packaging, plastic bags, oil container	Big-bags, garden furniture, car bumpers	Mirrors, lenses, beakers, cutlery
Technical notes	PE-LD (low density) used for packaging and film PE-MD (medium density) & PE-HD (high density) are stiffer, stronger and used for containers and pipes	Properties of PP are similar with PE-HD, but PP is stiffer and more though Inexpensive and a light material	Cheap polymer but very brittle, it breaks easily The mechanical loading is light There is not much polystyrene used in large products
Useful for inner bag?	Yes, excellent	No, too stiff	No, too brittle

However, for the examination of the most suitable one of these three selected plastics, more points of view need to be considered than only the costs and the technical characteristics. These are on the one side the 'Embodied energy' in the primary production and on the other side the 'CO_2 footprint' for the production process of each plastic.

The wet grain package should be an eco-friendly product. Energy usage and CO_2 emission must be acceptable. As shown in the following Figure 38, two polymers, Polypropylene (PP) and Polyethylene (PE), do not differ a lot in their values 'Embodied energy' and 'CO_2 footprint'. But still, Polyethylene has better characteristics than Polypropylene. The third polymer, Polystyrene (PS), was not suitable regarding its technical characteristics and its eco-friendliness is now far worse than the value of the other two plastics. It is not of interest to produce an inner bag out of this plastic.

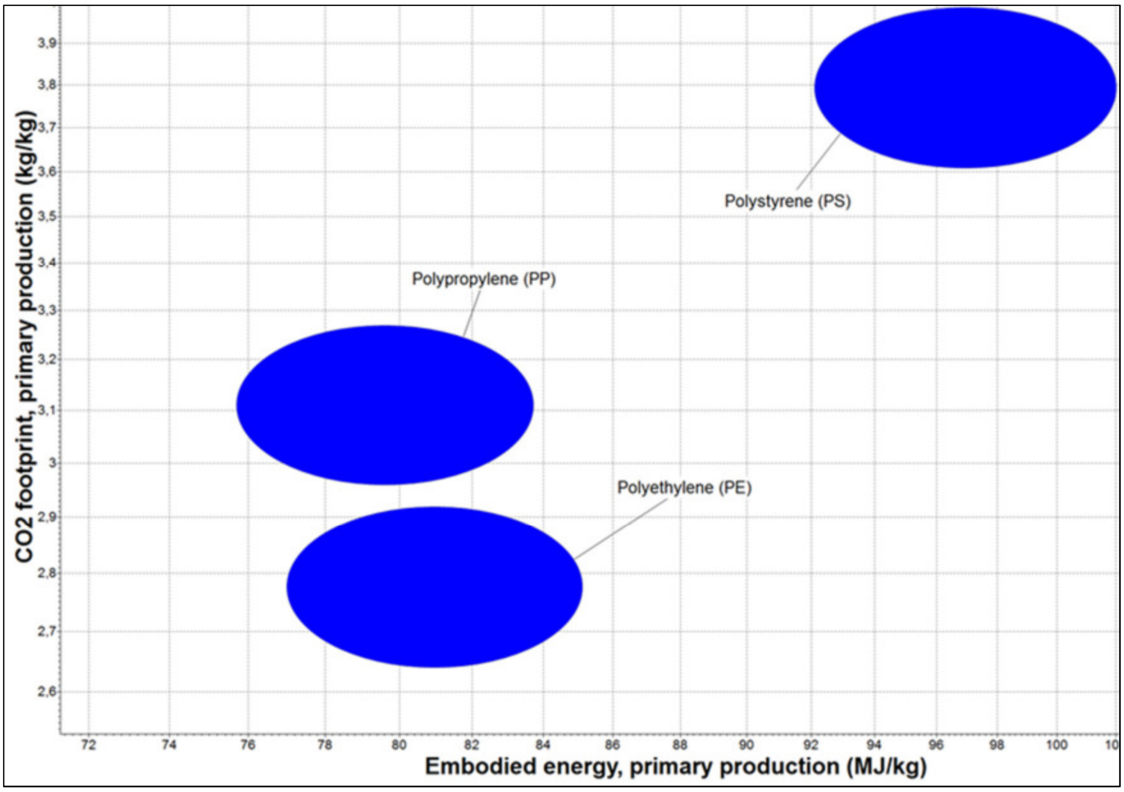


Figure 38: Comparison of the 'Embodied Energy' and the 'CO_2 footprint' of PE, PP and PS

This comparison regarding the ecological aspects showed that Polyethylene (PE) is the most suitable material for the requirements of the inner bag of the new wet grain storage units.

5.2.8.3 Suitability analysis of biodegradable plastics

Nowadays, there are also biodegradable plastics available. The definition of biodegradable:

'Capable of being broken down (decomposed) by the action of microorganisms.' (BusinesDictionary, 2017)

The most common biodegradable polymers are listed below:

- **PHA** Polyhydroxyalkanoates
- **PCL** Polycaprolactone
- **PLA** Polylactic acid
- **PGA** Polyglycolic acid

Polyhydroxyalkanoates are naturally produced polymers by bacterial fermentation of sugar or lipids derived from corn oil, palm oil or soybean oil.

Unfortunately, just putting these plastics after use on a landfill or putting it in the ground will not break them down. Every biodegradable plastic has its own degradation mechanism and properties. For example, PLA only degrades at temperatures above 60 degrees Celsius, and creating these conditions costs energy, which pollutes the environment. Therefore, biodegradable plastics are not the solution for plastic waste.

In addition, the raw materials for biodegradable plastics are created on agriculture sites. An ethical choice should be used regarding all the people, who are starving, while others would make food to a plastic replacement.

A further point is the economical aspect. Polylactide, the biodegradable plastic that can be used for disposable bags, is also more expensive compared to polyethylene. The density of the material and the cost make the polylactide polymer not an economical usable material, as shown in the graph below.

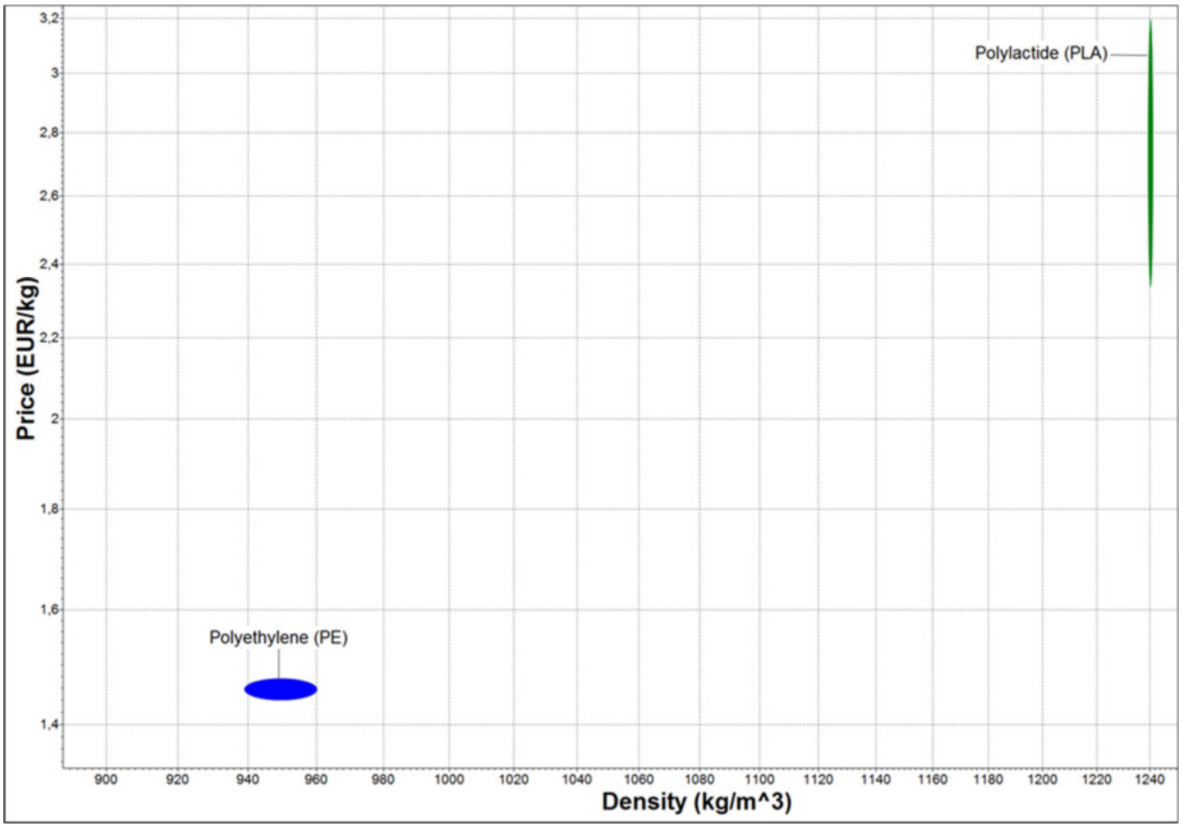


Figure 39: Comparison of selected plastics by their density & price per kilogram (inner bag)

The biggest disadvantage is the fact that the biodegradable plastics are not able to contain weak acids for a longer period. Altogether these characteristics of the biodegradable plastics prohibit the use of this material to produce inner bags. Nevertheless, biodegradable plastics will be developed, and it is possible that they can be used in the future.

5.2.8.4 Comparison with available techniques on the market

Polyethylene is with an amount of 30% the most used common plastic in the world. Typical products out of Polyethylene are packaging foils or cases. Polyethylene can be classified by its density and its structure:

- **PE-LLD** Linear, low density
- **PE-LD** Low density
- **PE-MD** Medium density
- **PE-HD** High density
- **PE-UHMW** Ultra-high molecular weight
- **PE-X** Cross-linked polyethylene

The following figures show some products and the required density levels of the Polyethylene raw material.

Figure 40: Plastic wrap (PE-LD)

Figure 41: Bottle (PE-LD)

Figure 42: Pipe (PE-X)

An analysis showed that the Polyethylene with a low density (PE-LD) is the most common and suitable material in the field of application as a packaging material for wet grain. Polyethylene with a low density is also used to create the big tubes and shows here its excellent resistance against acids.

The product lifecycle for PE-LD can be seen in the Figure 43. The part ‘Extrusion’ can vary, depending on the used type of Polyethylene and the required product.

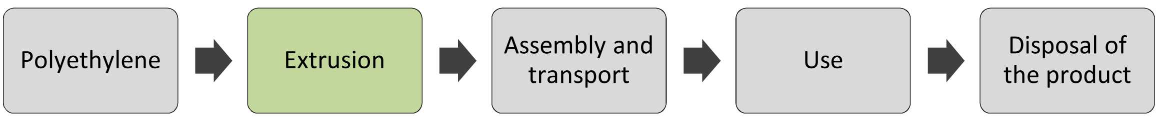


Figure 43: Production process for Polyethylene (PE)

The comparison validates the theoretical characteristics of Polyethylene (PE-LD) in practice and shows that the Polyethylene is a good choice to get an economical feasible material.

5.3 Investigation about the handling of the plastic waste that arises from the new developed storage units

The wet grain package consists of an inner and an outer bag. The materials used for the bags are polymers and because of this fact, it is important to look at the environmental impact of the product. This chapter presents various possibilities to handle the plastic waste, compares these options regarding their energy consumption and their CO_2 footprint and gives a conclusion about the possible commercial value of the plastic waste.

5.3.1 End of life 'Outer bag'

The outer bag is out of woven Polypropylene fibers. This durable composition qualifies the outer bag for the process of '**Reuse**'. In a research and in meetings with the supervisor Niklas Frände, the team examined that the outer bag can be used at least four times before the bags are too damaged and need to be exchanged.

A big advantage of the material Polypropylene of the outer bags is the possibility to recycle this plastic. A few steps are required to create a recycling cycle. The first step is to collect all the Polypropylene products. After that, it is important that the products get cleaned. After sorting the polypropylene, it is fed to an extruder. In this machinery the polypropylene will be melt at a temperature of 160° C and the extruder makes granules out of this mass. These granules can be used for the same product again or for creating a new or different product. (The Balance, 2017)

The recycling of used big bags out of Polypropylene is an established measure and it is recommended to get in contact with recycling companies to get more information what can be done with the used big bags out of the new developed wet grain packaging.

5.3.2 End of life 'Inner bag'

There are various methods to handle used Polyethylene. The project focusses on the handling of the waste which arises from used inner bags, because this waste will be created constantly. The following chapters compare the waste handling options regarding their 'Energy consumption' and their 'CO_2 footprint'.

5.3.2.1 Presentation of various waste handling options

When the big bag with the wet grain has been used, the outer bag and the inner bag are separated, and the outer bag will be reused for the same purpose. The future of the inner bag has not been determined yet. It is waste, but there are still multiple options for the material after its usage. Common processes are '**Reuse**', '**Remanufacture**', '**Recycling**', '**Downcycling**', '**Combustion**' and the deposit of the waste in '**Landfill**' sites. All these options have been analyzed and are presented in this chapter.

- **Reuse**

When, the with grain filled inner bag, has been used, reusing the bag would be the best option for the environment and the project 'Wet Grain in Package'. However, this method must meet the following requirements:

- After use, the bag needs to be cleaned up to a high purity degree to guarantee the further use as a food packaging.
- There will be a limit how often the bag can be reused because of the restrictions and required high purity degrees of food package materials.
- To take the grain out, a reusable opening feature is needed.

The requirements for packaging material of food regarding the purity degree are high and it could be that cleaning the bags costs too much time and water. Considering this aspect, the option 'Reuse' is not as green as it looks like.

+	-
Long life, less production	Cleaning costs
Easiest for the farmer	Limited use
No transportation back	Expensive design and manufacturing
	Opening feature required (zip)

The ecological footprint is shown in the Table 23 and Figure 44 below. The table represents the data for one kilogram of polyethylene. This data is collected from (Ecoinvent, 2017).

Table 23: Energy consumption and CO_2 footprint of 1-kilogram PE for the option 'Reuse'

Reuse	**Energy (MJ)**	**Energy (%)**	**CO_2 footprint (kg)**	**CO_2 footprint (%)**
Material	80,01	92,70	3,000	86,40
Manufacturing	6,09	7,10	0,467	13,20
Transport	0,00	0,00	0,000	0,00
Use	0,00	0,00	0,000	0,00
Disposal	0,20	0,20	0,014	0,40
Total (for first life)	86,30	100,00	3,470	100,00
EoL potential[2]	-80,01	-92,71	-3,000	-86,43

[2] End of life potential: energy/CO_2 saved/added because of option

The figures of the table are visualized in the graph. It shows a comparison of the classifications 'Material', 'Manufacturing', 'Transport', 'Use' and 'Disposal', and 'EoL potential'.

'**Material**' includes the energy to produce the raw material.

'**Manufacturing**', '**Transport**', '**Use**' and '**Disposal**' are the main steps in the lifecycle of a product.

The '**EoL potential**' means the amount of energy, which can be saved by using this waste handling method.

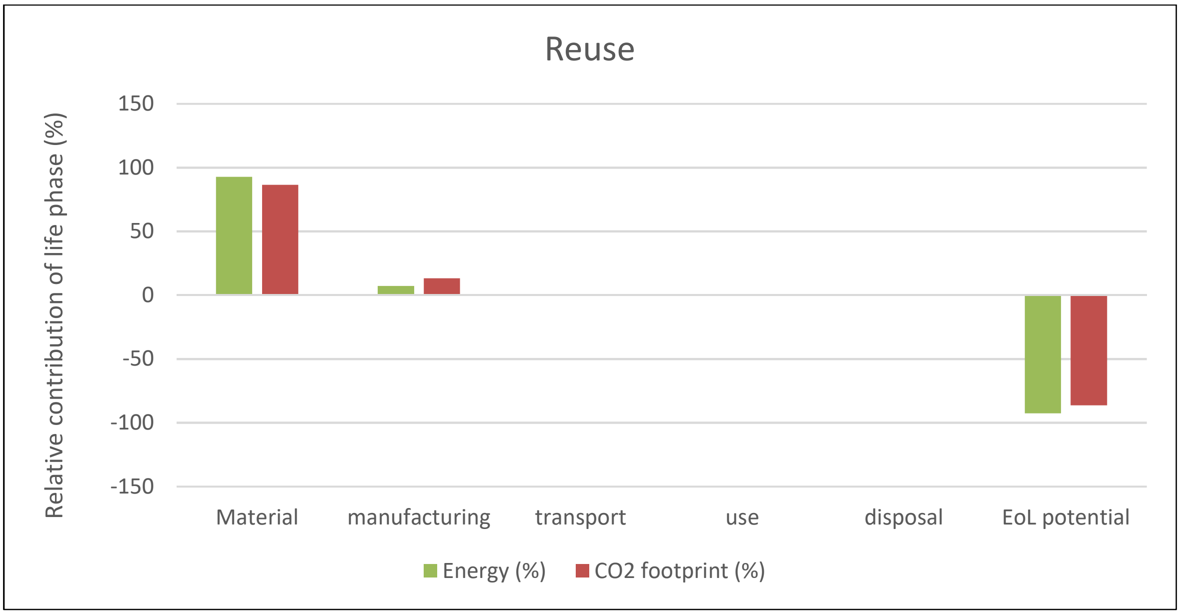


Figure 44: Comparison of the Energy consumption and CO_2 footprint for the option 'Reuse'

Transport and use numbers were left out, because the chapter investigates only the most suitable material for the wet grain packaging process.

Material will always have the highest contribution to the total product and this figure is always the same for all the waste handling options.

The percentages in the graph show that reuse of the product is nearly perfect. (EoL potential of 95%) This is because reusing the product spares the industry of creating a new product. Unlimited reusing (100%) a product is not realistic. At a certain point, even reusable products will find their end.

- **Remanufacture**

Remanufacturing means the bag is being transported back to the factory for restoring. The extra costs are the transportation back to the factory and the cleaning process. There must be a certainty that the warranty and other safety issues are still valid.

+	-
Using the same material or product again	Extra cost for remanufacturing
Less material used	Cleaning costs
	Transportation costs
	Because of the manufacturing, the condition needs to be checked again for warranty issues.

Nevertheless, remanufacturing is not a suitable option for the inner-bag because there is nothing to remanufacture. Melting it and putting the material in the production process is recycling. The project team recommends avoiding this term to eliminate misunderstandings.

- **Recycling or downcycling of the inner-bag**

Recycling means that the used material of the bag can be reintroduced into the cycle. The quality of the recycled product should be the same as the virgin one. There are two different approaches to recycle plastics:

Mechanical recycling - plastics become polymers again

Feedstock - create chemicals out of the plastic waste (e.g. fuel)

Figure 45 shows various materials and the number of recycled fractions of each category.

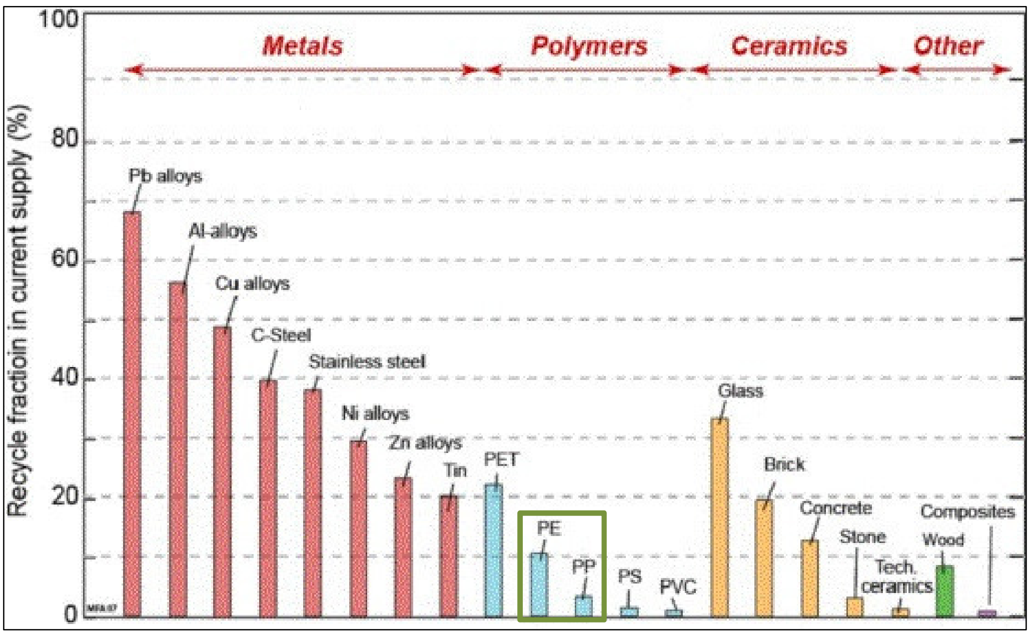


Figure 45: Recycle fraction in current supply ©CES-EduPack

The main matter of recycling is that the material for making new bags is coming from used bags. Of course, the amount of energy that is needed for the recycling process is never higher than the energy, which must be used for making virgin products. However, there is also a CO_2 emission when the plastics are being recycled. This makes recycling not the best sustainable option.

A lot of plastics come after recycling back in a secondary cycle. The virgin product cannot be recycled into the same product with the same characteristics and quality. This is because of all the additives in the plastic, like paint, other attached materials and sand or other dirt, which make it hard to wash and sort the plastic polymers properly. If the material is after its lifecycle almost in a virgin condition, creating the same or a product with a similar commercial value would be an option. Otherwise, it will always be downcycling.

Figure 45 shows that the Polymers are often below the 20% or even close to the 0%. This means that most of the plastics nowadays are being downcycled instead of recycled.

Table 24: Energy consumption and CO2 footprint of 1-kilogram PE for the option ‘Recycle’

Recycle	**Energy (MJ)**	**Energy (%)**	**CO_2 footprint (kg)**	**CO_2 footprint (%)**
Material	80,01	92,20	3,000	85,60
Manufacturing	6,09	7,00	0,457	13,00
Transport	0,00	0,00	0,000	0,00
Use	0,00	0,00	0,000	0,00
Disposal	0,70	0,80	0,049	1,40
Total (for first life)	86,80	100,00	3,510	100,00
EoL potential	-52,80	-60,83	-1,980	-56,47

Table 24 and Figure 46 show that recycling offers a high end of life potential (60%). Although, this would qualify recycling to be an excellent waste handling option, the project team decided after an intensive research not to follow this technique and to focus on the waste handling option ‘Downcycling’.

This waste handling method eliminates some of the risks, for example the possibility that the inner bag has even after cleaning residues of wet grain on it. The project team does not know how clean the new inner bags can be made. It is recommended to do some tests regarding this issue. Considering such risks, the waste handling option ‘Downcycling’ seems to be a practical feasible measure, which can be easier implemented at the start of the project ‘Wet Grain in Package’.

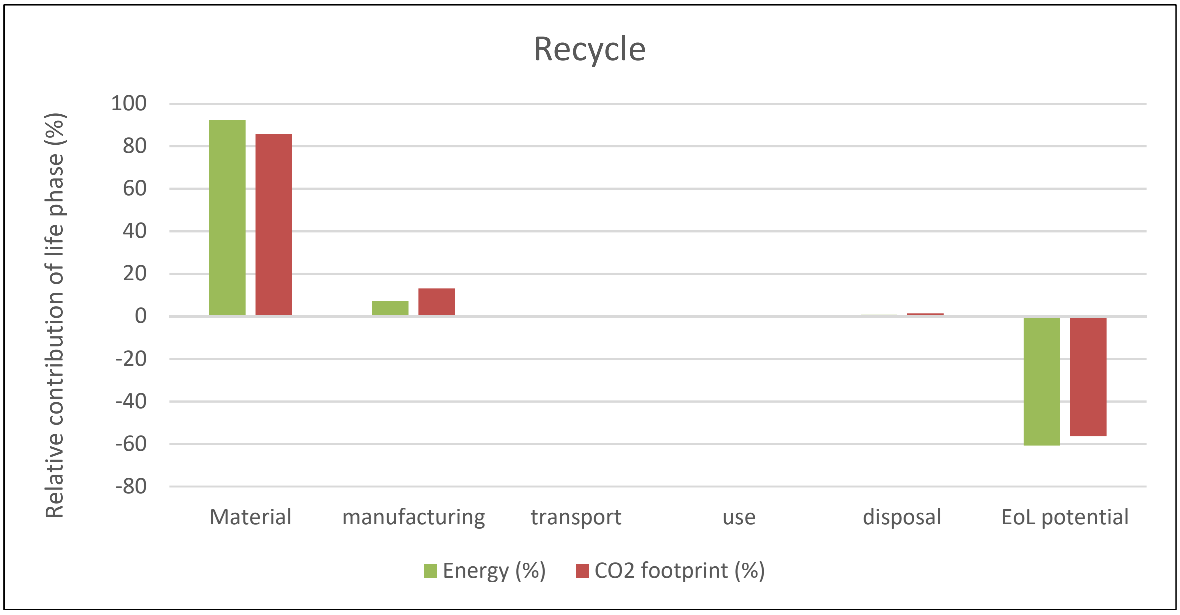


Figure 46: Comparison of the Energy consumption and CO_2 footprint for the option 'Recycle'

Successful downcycling can be seen by many products. For example, companies make insulation material out of used car seats for the construction industry. It does not matter if the product is not pure, because the requirements for the new product are not based on this aspect. For the inner bag of wet grain package, a similar approach should be used. A new product out of the used bags must be insensitive to clogging of the plastic material. A possible solution would be the production of trash bags out of the used inner bags.

An analysis of the energy consumption and the CO_2 footprint showed that in comparison to the recycling option, this waste handling option has a low End of Life potential (Energy -12,24%, CO_2 footprint -11,37%). But it is an approach to avoid plastic waste and it is a practical feasible option, which should be considered for the used inner bags.

Table 25: Energy consumption and CO_2 footprint of 1-kilogram PE for the option 'Downcycle'

Downcycle	**Energy (MJ)**	**Energy (%)**	**CO_2 footprint (kg)**	**CO_2 footprint (%)**
Material	80,01	92,40	3,000	85,90
Manufacturing	6,09	7,00	0,457	13,10
Transport	0,00	0,00	0,000	0,00
Use	0,00	0,00	0,000	0,00
Disposal	0,50	0,60	0,035	1,00
Total (for first life)	86,60	100,00	3,490	100,00
EoL potential	-10,60	-12,24	-0,397	-11,37

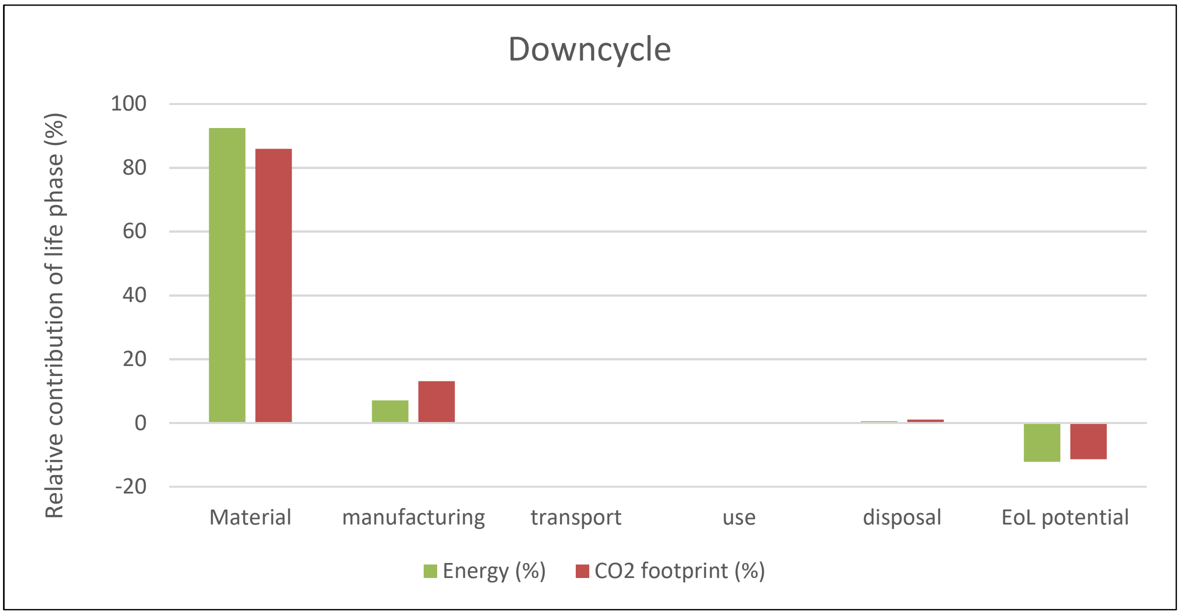


Figure 47: Comparison of the Energy consumption and CO_2 footprint for the option 'Downcycle'

- **Combust**

There is always the option to bring the material to a waste incineration plant for energy recovery. Here arise, because of burning the material, also CO_2 emissions at the end.

+	-
Easy end of life solution	Extra CO2 emission
Electrical energy source	Extra transportation costs
	Material not usable anymore (worse sustainable)

Combust is attractive, but burning the plastic waste emits a lot of extra CO_2. The burning process creates energy, around 15% end of life energy recovery. In contrast, the CO_2 emission by the burning process is around 65% of the total CO2 pollution of the product. This makes combust not the best sustainable end of life option.

Table 26: Energy consumption and CO_2 footprint of 1-kilogram PE for the option 'Combust'

Combust	**Energy (MJ)**	**Energy (%)**	**CO_2 footprint (kg)**	**CO_2 footprint (%)**
Material	80,01	92,40	3,000	85,90
Manufacturing	6,09	7,00	0,457	13,10
Transport	0,00	0,00	0,000	0,00
Use	0,00	0,00	0,000	0,00
Disposal	0,50	0,60	0,035	1,00
Total (for first life)	86,60	100,00	3,490	100,00
EoL potential	-11,30	-13,05	2,350	67,30

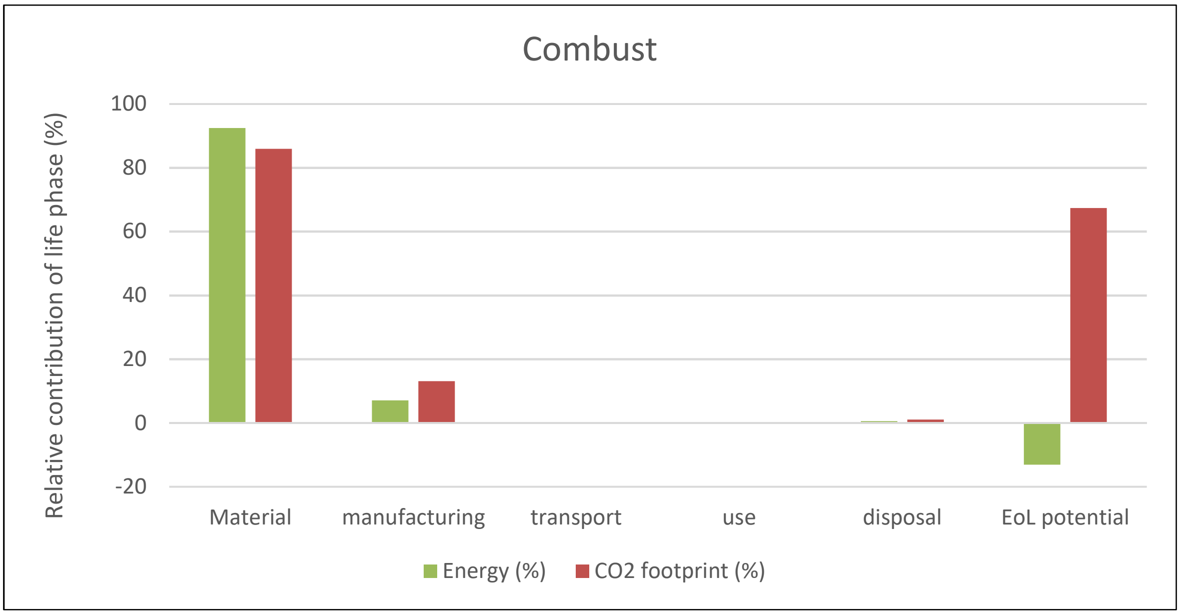


Figure 48: Comparison of the Energy consumption and CO_2 footprint for the option 'Combust'

The project team examined that in the project region of Vaasa, and especially in Sweden, a majority of the plastic waste goes to waste incineration plants. It is an energy-efficient and common process, but higher restrictions of the governments and the European Union regarding the CO_2 emissions make it likely that the incineration of waste for energy recovery purposes will be regulated in the future. It is recommended to avoid this waste handling option if it is possible.

- **Landfill**

Landfill is the least attractive option of all the presented waste handling measures. When the product is used, it will be transported to a landfill site to dump it in prepared areas. No end of life energy benefits can be created by using this option.

+	-
Easiest solution	Material will be on the landfill forever
	No energy recovery from material
	Takes space (land)

The biggest disadvantage of this method is the low level of degradation. Experts estimate that plastics need hundreds of years till they are completely decomposed by microorganisms. In addition, scientists investigated that microplastics accumulate in the body of animals and it is not possible to assess the risks out of this issue yet.

Table 27: Energy consumption and CO_2 footprint of 1-kilogram PE for the option 'Landfill'

Landfill	**Energy (MJ)**	**Energy (%)**	**CO_2 footprint (kg)**	**CO_2 footprint (%)**
Material	80,01	92,71	3,000	86,43
Manufacturing	6,09	7,06	0,457	13,17
Transport	0,00	0,00	0,000	0,00
Use	0,00	0,00	0,000	0,00
Disposal	0,20	0,23	0,014	0,40
Total (for first life)	86,30	100,00	3,470	100,00
EoL potential	0,00	0,00	0,000	0,00

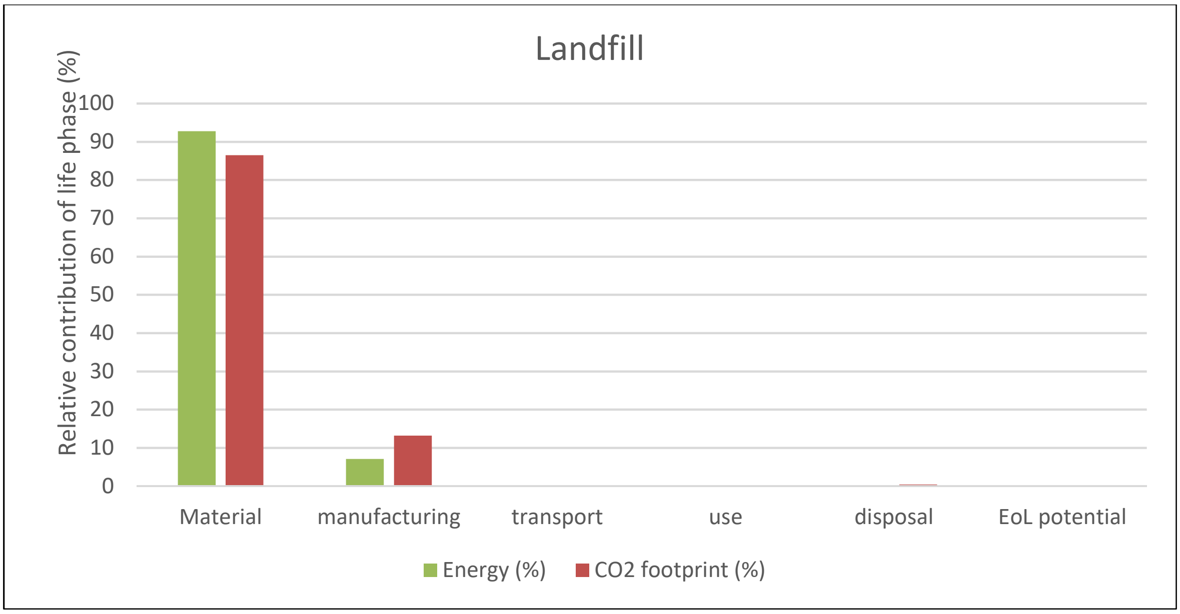


Figure 49: Comparison of the Energy consumption and CO_2 footprint for the option 'Landfill'

Considering these facts and the missing End of Life potential of this waste handling option, the project team does not recommend this option. However, it is used in the following comparisons of the waste handling options regarding their energy consumption, the CO_2 footprint and the commercial value of the plastic waste.

5.3.2.2 Comparison of 'End-of-Life' options by their used energy

This comparison only focusses on the required energy for each stage in the product lifecycle. It can be seen in Table 28 that the used energy for the 'Material' and the process 'Manufacturing' are the same for each option, because the same product was analyzed for each measure. 'Transport' and 'Use' are not used for this analysis and are only used to show the product lifecycle without any gaps. The single waste handling options differ in the aspects 'Disposal' and 'EoL potential'. The point 'Energy balance' shows the difference out of the 'Total Energy (first life)' and the 'EoL potential' and is the unit of measurement in the Figure 50. All the data is valid per kilogram of Polyethylene of low density (PE-LD).

Table 28: Comparison of the selected waste handling options by 'Used energy' per kg

Used energy (MJ)	**Landfill**	**Combust**	**Downcycle**	**Recycle**	**Reuse**
Material	80,01	80,01	80,01	80,01	80,01
Manufacturing	6,09	6,09	6,09	6,09	6,09
Transport	0,00	0,00	0,00	0,00	0,00
Use	0,00	0,00	0,00	0,00	0,00
Disposal	0,20	0,50	0,50	0,70	0,20
Total energy (first life)	86,30	86,60	86,60	86,80	86,30
EoL potential	0,00	-11,30	-10,60	-52,80	-80,01
Energy balance	86,30	75,30	76,00	34,00	6,29

The figures show that reusing and recycling are the least energy consuming options and that downcycling and burning have a high and similar energy consumption.

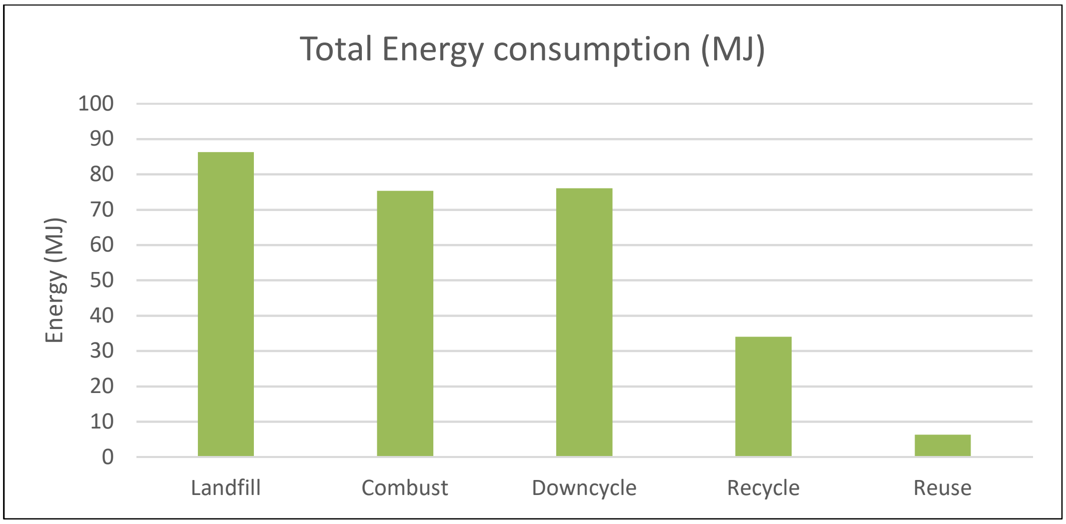


Figure 50: Comparison of the waste handling options by their 'Energy balance'

5.3.2.3 Comparison of ‘End-of-Life’ options by their CO_2 footprint

The comparison looks on the CO_2 footprint of each phase in the product lifecycle. Table 29 shows the figures for each waste handling option. The CO_2 footprints for the ‘Material’ and the process ‘Manufacturing’ are the same and the aspects ‘Transport’ and ‘Use’ are only used to show the product lifecycle without any gaps. The single waste handling options differ again in the aspects ‘Disposal’ and ‘EoL potential’. The point ‘CO_2 balance’ is the difference between the ‘Total CO_2 (first life)’ and the ‘EoL potential’ and the unit of measurement in the Figure 51. The data is valid per kilogram of Polyethylene (PE-LD).

Table 29: Comparison of the selected waste handling options by ‘CO_2 footprint’

CO_2 footprint (kg)	Landfill	Combust	Downcycle	Recycle	Reuse
Material	3,000	3,000	3,000	3,000	3,000
Manufacturing	0,457	0,457	0,457	0,457	0,457
Transport	0,000	0,000	0,000	0,000	0,000
Use	0,000	0,000	0,000	0,000	0,000
Disposal	0,014	0,035	0,035	0,049	0,014
Total CO2 first life	3,471	3,492	3,492	3,506	3,471
EoL potential	0,000	2,350	-0,397	-1,980	-3,000
CO2 balance	3,471	5,842	3,095	1,526	0,471

The visualization of the figures shows the advantage of the option ‘Downcycle’, which has half of the CO_2 footprint in comparison with ‘Combust’. Considering the ecological impact, downcycling is together with the options ‘Reuse’ and ‘Recycling’ the most suitable option.

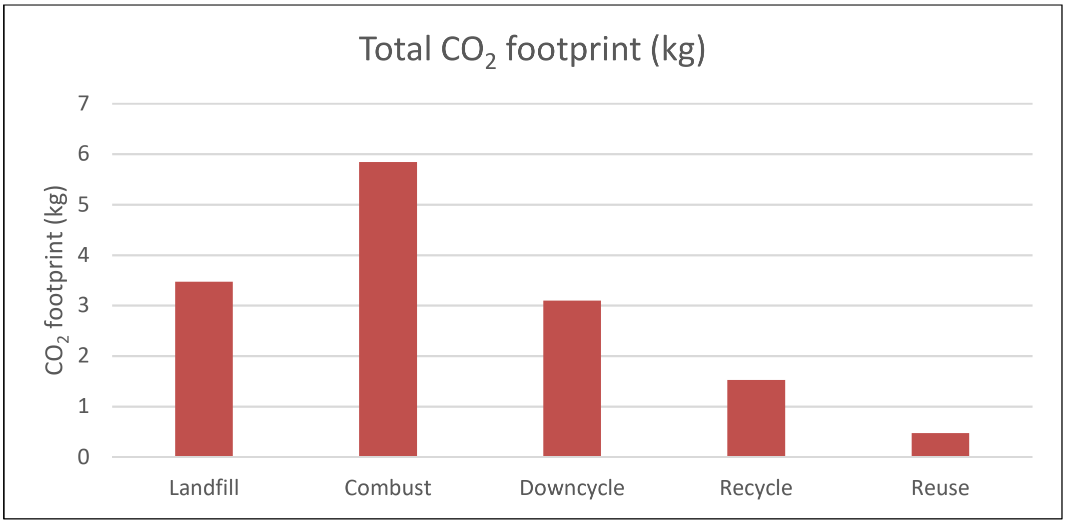


Figure 51: Comparison of the waste handling options by their ‘CO_2 footprint’

5.3.2.4 Selection of the most suitable EoL option for the inner bag

Considering the results of this detailed analysis, the project team decided, in consultation with the supervisor Niklas Frände, that the options ‘Downcycle’, ‘Recycle’ and ‘Reuse’ should be reviewed to examine the most suitable solution for the wet grain packaging bags. In a meeting, the Swedish expert Hans Arvidsson, confirmed that there is a high probability of dirty inner bags, which cannot be cleaned properly. He recommended not to use the option ‘Reuse’. It would require an intensive and difficult cleaning process to reach a purity degree, which allows the further use of the bags as packaging material for food. After this conversation and a detailed research about the characteristics of the two remaining options ‘Recycling’ and ‘Downcycling’. Because recycling is technically not possible, the project team chose the downcycling process as the most suitable measure to handle the waste out of used inner bags.

5.3.3 Commercial value plastic waste

Beside of the complexity of the waste handling techniques and the ecological impact of each option, the commercial value per Kilogram of waste is of interest.

The most important aspect for the end of life of the plastic is that the local farmer should be convinced by the option. It needs to be economical feasible. The Table 30 shows a comparison of the value of waste after using the single waste handling options. All the waste handling options are listed to get a better view of the single figures and to see the advantages of recycling and reusing.

Table 30: Comparison of selected waste handling options by the ‘value of the waste’

Option	**Costs description**	**Value waste end (Euro/kg)**
Landfill	On short notice, if its legal, no additional costs for the farmer	0,000
Combust	Collect plastic and transport to a waste incineration plant	0,400
Recycle	Value recycled plastic granulate	0,711
Reuse	Value of first product	-

The option ‘Landfill’ does not generate any value out of the waste. A ‘Combust’ process generates energy, which gives the waste a value of 0,40 € per Kilogram. The big disadvantage is the environmental pollution and the costs to remedy the damages are not included in this value. It is likely that the government will regulate this option by fees in the future, which makes this option an uncertain measure to gain value out of waste.

'Recycle' and 'Reuse' have a better future and the value, which can be generated out of waste by using these options, is predicted to increase constantly. The value of recycled plastic granulate is approximately 0,71 € per Kilogram and in the case 'Reuse', the value of the waste nearly corresponds to the value of the virgin or first-use product.

Figure 52 shows the average prices for Polyethylene with a low density on the market.

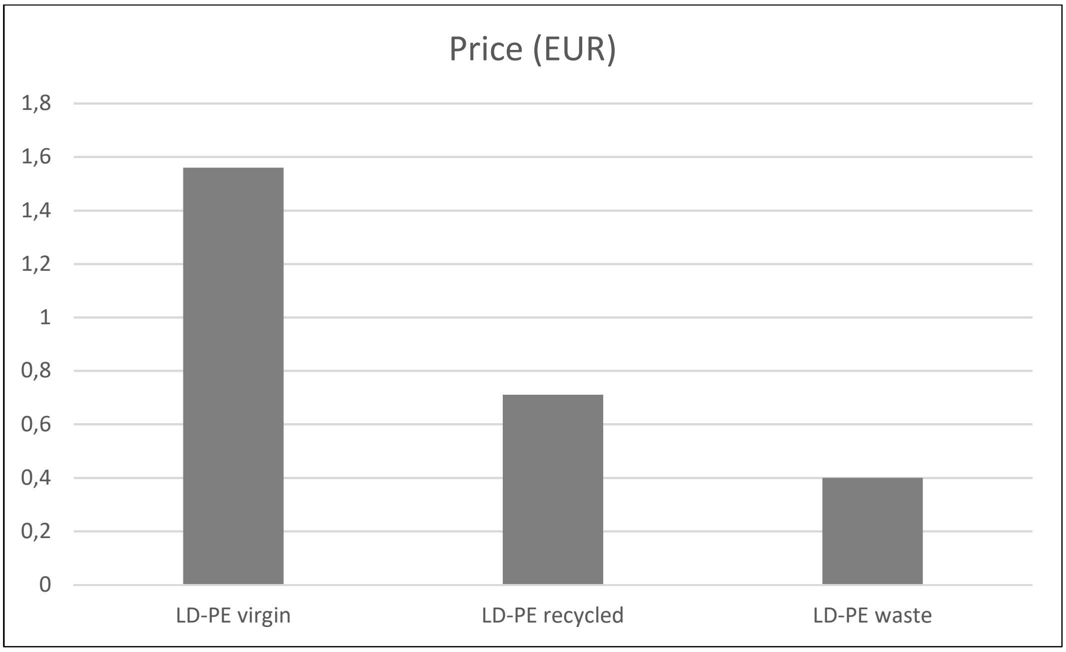


Figure 52: Comparison of Polyethylene (PE-LD) by its prizes in different life-cycle phases

The data shown in the Table 30 and the Figure 52 are from (Plasticker, n.d.).

5.3.4 Examples for possible products out of the recycled plastic waste

Several researches on the topic ‘Products out of agricultural waste’ showed that there are various products out of recycled plastic waste for both polymer material families, Polypropylene (PP) and Polyethylene (PE-LD). The most useful source was the website and the information material of the French association ‘ADIVALOR’. This is a non-profit industrial society, which was founded in 2001 by several French producers of plant protection products to take care of the waste which arises from the usage of the protection products and their package material. The mission of this association is the consultation of companies and trade houses to decrease the amount of waste and the introduction of waste reducing measures. Further information about ‘ADIVALOR’ can be found on the website www.adivalor.fr/en/. Both examples for products out of used Polyethylene and Polypropylene products can be seen in movie clips on the YouTube channel of ‘ADIVALOR’.

- From **old big bags** (Polypropylene PP) … … to a **new plastic chair**.

Figure 53: Pictures out of the YouTube clip of ADIVALOR about recycling Polypropylene

The bags are collected without washing them. They are cleaned by several machines by a recycling company in a factory. After various shredding steps, an extruder makes first panels out of the waste and these bigger plastic parts are cut into granulate. In a last step, an injection molding machine makes garden chairs out of this granulate.

- From **old plastic films** (Polyethylene PE) … … to **new garbage bags**.

Figure 54: Pictures out of the YouTube clip of ADIVALOR about recycling Polyethylene

A similar process is required to produce garbage bags out of used Polyethylene films. The cleaning phase is more difficult and intensive than for the recycling of big bags. A blow molding machine makes new films out of the granulate to make the final trash bag out of it.

The project team did not find any information about the required amount of waste per recycled product to calculate the profit out of producing and selling these products. It is recommended to get in contact with a recycling company to discuss this aspect.

5.3.5 Calculation of the profit out of recycling the new packages

5.3.5.1 Costs wet grain package

The costs of the wet grain package are divided in two different products, the inner bag foil and the outer bag.

The following aspects are considered for the price of the inner bag:

- Material costs
- Production costs
- Profits
- Extras

The thickness is important for the calculation of the weight of the bag. There are multiple thickness options available:

- 25 microns Extra Lightweight
- 40 microns Economy Weight
- 50 microns Standard Weight
- 80 microns Medium Weight
- 100 microns Heavy Weight

For the inner bag the plastic low density polyethylene is chosen, the thickness of the layer will be 80 microns.

Figure 55 Example of an 80 microns polyethylene bag ©Interplas.com

The dimensions of the bag are 1000x1000x1000, so a cube with six sides can be used as a model to calculate the material usage for one of the new bags:

$$6 * 1000 * 0{,}08 / (1000 * 1000) = 0{,}00048\ m3$$

Price LD-PE/m3 (Euro)	*1375*
Volume material bag (m3)	*0,00048*

Material price of the product: $1375 * 0{,}00048 = 0{,}66\ Euro$

The production costs are the costs of the polymer extrusion, and for this purpose the CES-EduPack calculation is used. It is based on the following parameters:

Table 31: Parameters for the calculation

Capital costs		**Variable costs**	
Capital costs (EUR)	6e5	Capital write-off time (year)	5
Tooling costs (EUR)	4,5e5	Material costs (EUR/kg)	1,45
		Component mass (kg)	0,60
		Batch size (-)	1e3
		Component length (m)	1
		Overhead rate (EUR/hr)	134
		Discount rate (%)	5
		Load factor	0,5

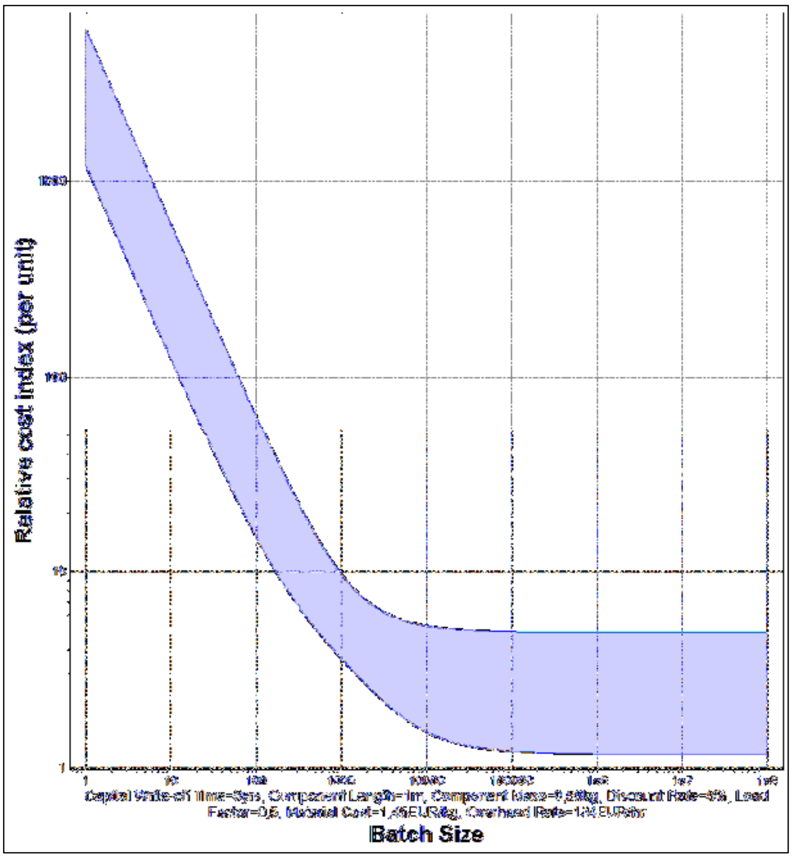


Figure 56: Batch size

Equation used[3]

The relative cost index gives the percentage of the production costs for the price of the total product. In the graph there is at a batch size of 1000 the cost index of 8, this means that the polymer extrusion costs are 8 percent of the whole price of the inner bag.

Developing costs and transportation of the product are also numbers to consider, but mass-production products mostly have a few percentages for these costs, about 5 percent. There will also be a margin in the total price for the profit of companies, this is around 50 percent.

- **Profit factor**

The production factory and all the involved companies by making the product are making profit, mass produced products mostly have a 1,5 factor. This means that 1/3 of the price is going to the companies for profit.

- **Price for one inner bag**

The equation for the price is:

$$material\ price\ *\ production\ factor\ * profit\ factor *\ extra's\ factor$$

The price for one inner bag: $0{,}66 * 1{,}08 * 1{,}05 * 1{,}5 = \ 1{,}12\ Euro.$

- **Price for one outer bag**

For every inner bag there is an outer bag needed, the costs for a big-bag on the market are around the 10 euro's.

- **Total price**

Because the outer bag is reused multiple times, the costs for the whole wet grain package is around 12 euro's when the farmer starts using this product. The year after he only needs

[3] $(([Parameter: Material\ Cost]\ *\ [Parameter: Component\ Mass])\ /\ [Material\ utilization\ fraction]\ +\ ([Tooling\ cost]\ /\ [Parameter: Batch\ Size])\ *\ (1\ +\ ([Parameter: Batch\ Size]\ /\ ([Tool\ life\ (length)]\ /\ ([Parameter: Component\ Length]))))\ +\ (1\ /\ ([Production\ rate\ (length)]\ *\ 3600\ /\ ([Parameter: Component\ Length])))\ *\ [Parameter: Overhead\ Rate]\ +\ (1\ /\ ([Production\ rate\ (length)]\ *\ 3600\ /\ ([Parameter: Component\ Length])))\ *\ ((([Capital\ cost]\ *\ (1\ +\ ([Parameter: Discount\ Rate]\ /\ 100))\text{^}[Parameter: Capital\ Write-off\ Time])\ /\ ([Parameter: Capital\ Write-off\ Time]\ *\ 24\ *\ 365\ *\ [Parameter: Load\ Factor])))$

to purchase the inner bags. The outer bags can easily be reused four times, so the average price of the whole wet grain package with considered the write-off time of the outer bags is:

$1{,}12 + \frac{10}{4} = 3{,}62$ Euro

5.3.5.2 Waste volume and weight

To calculate the volume of the plastic waste in one year after the inner bag has been used the following equation is used:

$$Quantity\ inner\ bags\ (-) * \ material\ volume(m^3)$$

$$92 * 0{,}00048 = 0{,}044\ m^3$$

Calculated the weight with the density of the PE-LD (950 kg/m^3):

$$0{,}044 * 950 = 41{,}8\ kg$$

This amount of waste arises after one year of using the wet grain packages.

5.3.5.3 Recycling costs

For the material of the inner-bag, low density polyethylene, recycling is the best end of life option in case of CO_2 combust and energy costs. Take note that recycling here means the recycle into the secondary circle, there is no possibility that the plastic is recycled in the primary circle where the same product can be made from.

The scenario of the calculation:

- Agricultural waste
- Only plastics
- Nordic county's (Scandinavia)
- Total recycles

The following steps will be included in the calculation:

1. Collection of waste at the farm and transporting to sorting facilities
2. Pre-treatment and sorting plastics
3. Transportation to recycle facilities
4. Recycle to granulate

- **Collection of waste**

It is relatively easy to collect plastics at a farm, the used inner bags can easily be collected and put into storage. The average price of the total collection of agricultural waste is 50 Euro/ton plastic.

- **Pre-treatment and sorting of plastic waste**

The average costs of the pre-treatment and sorting of the agricultural waste is 100 Euro/ton material.

- **Transport to recycle centers**

Included for the transport costs is: employee costs, average travel distance, truck size. The average costs for transport is 15 Euro/ton plastic.

- **Recycle costs**

The recycling of the material is the most expensive step in the process, the average recycling price is 500 Euro/ton plastic. This includes the recycle equipment, employee costs and energy costs.

Data source: (Mathieu Hestin, 2015)

- **Total costs**

Name	Price (EUR/T)
Collection waste	50
Pre-treatment and sorting of plastic waste	100
Transport to recycle centers	15
Recycle costs	500
Total costs	665

The total costs of the recycle process is 665 Euro per ton, this is around 0,67 euro per kg PE-LD.

The average costs of recycled PE-LD are around 800 Euro/t, this is about 0,8 euro per kg.

5.3.5.4 Profit for the farmer

To come to the profit for the farmer, all facts are presented in the table:

Name	Value
Price inner bag (Euro)	1,12
Price outer bag (Euro)	7,5
Total recycle costs (Euro/kg)	0,665
Waste value (Euro/kg)	0,13

Scenario (one year):

Name	Value
Harvested grain (m3)	92
Packages needed	92
Costs inner bags (Euro)	104,6
Costs outer bags (Euro)	697,5
Total costs packages (Euro)	802,1
Amount of waste (kg)	41,8
Value waste (Euro)	5,43

The value of the plastic waste is then 0,13 Euro per kg waste.

The farmer can get at least 0,13 euro per kg of plastic waste, the amount of plastic needs to be enough to convince the farmers to provide the recycle sector with their plastic waste.

5.3.6 Required purity degrees and cleaning technologies

When considering the recyclable package, cleaning after use is important. On the market, there is a value for clean PE-LD scrap as the waste can be of value when it is properly cleaned.

Pre-washing the plastic waste is the task for the consumer of the product, or in the case of 'Korntainer' the task for the farmer. The following procedure is significant for making the greatest value out of the plastic waste:

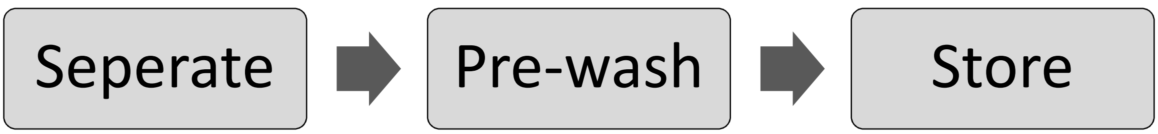
1. Sorting the recyclable material waste and keep out all other materials
2. Clean the plastic from dirt, sand, mud and left-over grain
3. Store the plastics in a clean place where they cannot get dirty again

Current waste pick-up projects show pictures and requirements for the waste they want to for making clear how clean the waste needs to be. For example, a waste collector in Germany shows the clean-rules as one can see in the Figure 57.

Figure 57: Pictures showing the required purity degrees

Cleaning the inside of the inner-bag is the easiest when the bag is inside out and then gets sprayed with water. This will remove the remains of the grain Because the inner-bag is not that big, this process can be done at any farm and with a normal water-hose.

The most important steps:



Sorting is required in the first place because waste from the same material will be put into a shredder for making granulates at the recycle factory. Other materials like wood or steel will demolish the machine. The main-wash happens at the recycle factory thus plastic waste can be of a higher value, when it has been cleaned properly before. Hans Arvidsson told the team that in Sweden the farmers do not pre-wash their plastic waste before, but sort it by their type of plastic. In Sweden, the whole washing process is done in the recycling factories. In these factories various industrial machines are used to wash the waste properly to avoid greater damages of the following production machines, like extruders.

Which machines are necessary to clean the plastic in a way it is usable to get a new secondary product out of it?

The first step, after the waste is delivered to the factory, is to cut and clean the plastic. The cleaning process starts with a washing drum, as shown in Figure 58. This drum rotates with between 6 and 10 rotations per minute. The rotations cause separation between large pieces of plastic and unwanted, smaller pieces, such as wood and glass. These parts can fall through a screen and are collected. There is a possibility to add water with some cleaning chemicals to clean the plastics of strong acids or paint.

Figure 58: Washing drum ©Plasticrecyclingmachine

A dewatering machine will be used to get rid of the moisture that is left on the plastic. The machine consists of a screw shaft surrounded by an outer casing wall. The screw shaft is rotating slowly when the plastic is feed into the feeder. The screw shaft becomes thicker in its diameter at the end and the space between the screw shaft and outer casing wall becomes smaller. At the end the space is so compact that the moisture from the plastic is squeezed out.

Figure 59: Dewatering machine ©Plasticrecyclingmachine

Big pieces of plastic will be shred apart by a shaft shredder. Rotated shear blades slowly rotate into each other and this causes a cutting motion. The shredding part is required to make granulate from the plastic films, because the packaging foils are often big and need this shredding process to fit into the extruder.

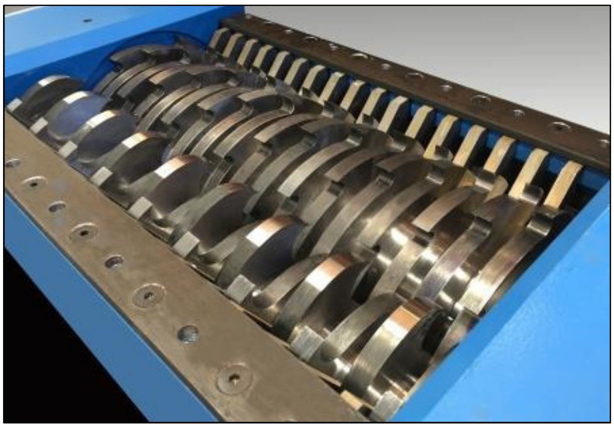


Figure 60: Shredder Machine ©Powderbulksolids

At the end, an extruder will produce granulate out of the cleaned plastic parts. As a first step, the plastic is melted down to a liquid state and transported to the extrusion head by a screw shaft. Long threads of melted plastic will come out of the extrusion head and are cooled down in a water bath. A cutting machine will make granulate of the plastic threads. The polymers, which are recycled in this way, are thermoplastics. This means, the polymer fibers can be moved by using heat. That is why the plastic granulate can be melted down several times to produce a secondary product.

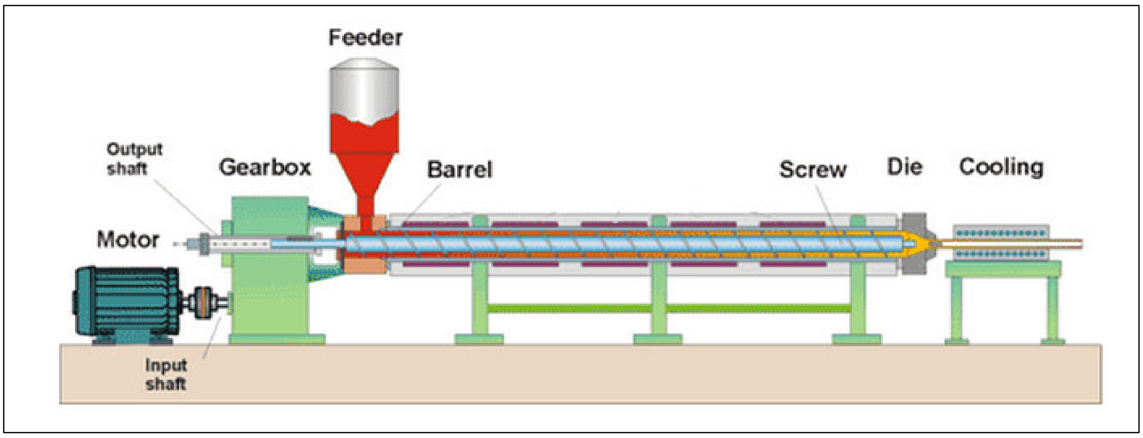


Figure 61: Extruder ©Feed-pellet-machine

One suggestion of the Swedish expert, Hans Arvidsson, which should be considered by the project team, was to create a small facility to recycle or downcycle the plastic waste which arises from the new type of packaging. The team ‘Korntainer’ analyzed, if this idea is feasible.

First, it is worth it to look at a setup of a small facility which downcycles the plastic waste of the agricultural sector. The first suggestion of Hans Arvidsson is to clean all the plastic waste at a collection point in a certain area. This can be done by a machine but also by hand, it depends on the requirements of the factory. A machine will clean the inner bag better as when an employee cleans the bags by hand. The only difference will be the costs. A washing drum costs around 45.000 € and will not be used all the time because there will be not enough plastic waste in an area, which has such a low density of population like in Finland. This means the machine cannot run for 24 hours a day. Even if the person gets paid for the cleaning process, it will be hard to get any profit out of this. Also, there must be enough space for the machine and to collect all the waste around the machine. The only advantage in this option is that a factory does not have to clean the plastic before the downcycling process.

The second option is to develop a production line with help of a few farmers who want to invest in the production line. To create a whole production line, it needs a lot more investment, not only in machines but also in employees, a bigger location and installation costs. For the whole downcycle process, it is necessary to have the following machines:

- Washing drum
- Dewatering machine
- Shaft shredder
- Extruder
- Conveyor-belt

These machines are all quite expensive considering the low amount of plastic which can be collected in a specific area. Even if it is possible to sell the secondary product out of the downcycling process, it would need many years to make any profit. Apart from the machinery costs, there will be other costs as renting a certain location, the cost for the installation and there is a need for an operator, who has the control over the production line. But the main problem will be the lack of plastic waste to run such a waste recycling plant for 24 hours a day with the goal to gain money. The expenses for the machines and the external costs would be too high.

The project team decided that it is not possible to use a decentral recycling solution with the current recycling technology.

5.3.7 Edible plastics and their suitability for the inner foil of the bag

Recycling or downcycling plastics requires much time, energy and industrial machines. How much easier would it be to store the food in a packaging material, which can also be eaten, or which can be mixed into the normal feeding to give it to the livestock? This chapter analyses the status of the technology 'Edible Plastics' and its suitability for the new product 'Wet Grain in Package'.

5.3.7.1 Short explanation of the term 'edible plastics'

Edible plastics are a type of plastic that could biodegrade efficiently, but mainly the plastics are designed for being eaten. This type of plastics is developed to replace the biggest environmental problem: The plastic waste problem.

5.3.7.2 Presentation of various edible plastics

The remain of plastic packaging after use is a big problem all around the world. It would be a big step forward if there were some solutions for this problem. A major development would be an edible packaging. The edible packaging would provide the grain from damage and after its use the farmer can mix it with the grain and feed it to the cows or to other animals on his farm. An edible packaging could lead to a reduction in the waste disposal problems.

Edible coating

Nowadays there are already a few solutions to replace plastic packaging by an edible coating. This coating is a layer of edible material around an edible product what improves the freshness and extend the quality of the food. These coatings are called 'controlled atmosphere (CA)' and 'Modified atmosphere packaging (MAP)'. The coating can carry active ingredients, that are used for protection and to maintain the characteristics of the product. The coatings are applied to the product to build up a protection against oxygen, moisture and even UV. Now the product can be transported in packaging that is better recyclable or biodegradable than plastic bags.

- **Ooho**

Ooho is a company who is using natural materials to create packaging. The packaging is made from plants and seaweed and is created to stop the waste from plastic bottles. This packaging method is an environmentally friendly way and is 100% made of plants and seaweed. The material is biodegradable in 4-6 weeks and is cheaper than plastic.

Figure 62: Edible packaging© Ooho.

Producing this edible plastic will cost less CO_2 emission and less energy than plastic packaging.

The material of this edible plastic is not strong enough to protect the grain, but with further developments in the future it may be possible to use it. Also, there is not enough information about the characteristics of this material. For example: Is it able to hold weak acids? Which chemicals cause a decompose of the edible plastic?

- **USDA**

Figure 63: Milk-based packaging ©USDA.

USDA (abbreviation for: **U**nited **S**tates **D**epartment of **A**griculture) has a scientific lab which develops edible, biodegradable or recyclable packaging. The packaging is made of a milk protein called casein. USDA is still in progress to develop this type of packaging. The milk-based packing keeps oxygen better out than plastic. This type of packaging will prevent that plastic packaging is sent to landfills. There are only a few doubts about this type of packaging, one of them is the concern about allergies. There is no information about the use of acids with this type packaging. But if the USDA can develop a packaging that is able to contain weak acids it would be a good solution for replacing the inner bag.

- **WikiCell**

Figure 64: Edible packaging © WikiCell

The idea was to create a way to package food and drinks by using only methods of nature. 'WikiCell' is the biggest company for products out of edible or biodegradable materials now. 'WikiCell' encloses food and drinks inside organic skins like orange peels and coconut shells. These types of packaging are completely biodegradable or in some cases even edible. The packaging is made of two layers. The first layer can keep water inside the main product, so it will not dry out. The second layer is a protective shell and completely edible or biodegradable. David Edwards is a co-founder of the company and the person behind the 'WikiCell'. His personal goal is to create an edible packaging what will solve the problem with plastic waste. David is also the founder of 'WikiFoods', 'WikiPearls' and 'Wikibar'. These small companies have been established to solve the plastic waste problems, too. (Spector, 2012)

Vivos® films

Figure 65: Edible packaging ©Vivios films

Vivos® films is created for packaging small amounts of food. The packaging is made of food grade ingredients. It disappears and releases their content when the packaging is in contact with hot or cold water. This idea is already used in a lot of food industries, restaurants and chef-cooks are proponents of the idea. This could be a solution for the material of the inner bag. But it is unclear whether the material is resistant to acids and if it the material can contain wet grain.

5.3.7.3 Future perspectives for edible plastics

There are already a lot of solutions to replace plastic packaging, most of these new type of packaging is created in the food industry. Nowadays the food industry is the biggest sector which creates edible packaging. Most of these type of packaging is made of a natural material, seaweed, Edible coatings like 'CA' and 'MAP' or shells from a coconut or an orange shell. These solutions are only used in food industry. Could these types of packaging be used in the agricultural sector? The major issue here is the lack of information about the characteristics of these edible materials. If the companies managed to develop the edible packaging and create a packaging that's able to contain weak acids it will solve one of a great environmental problem in the world, not only for using it in the agricultural sector but also in every sector where plastic is the biggest consumer.

5.4 Review of the project outcomes

At this point of the report, the team has already found solutions for all the main tasks, which were given by the supervisor Niklas Frände at the beginning of the project. The tasks were:

- Development of a useful design of the bags for the new storage technology
- Selection of a suitable material regarding the technical and ecological requirements
- Analysis of various waste handling options and their ecological impact
- Research about the commercial value of recycled waste and products out of it
- Required purity degrees and cleaning technologies for a recycling process
- Suitability analysis about edible plastics and their use as an inner bag

This chapter gives a summary of the results of these tasks and analyses their significance for the whole project 'Wet Grain in Package' by comparing with the big tube storing technology.

5.4.1 Summary of the results of the development process

The following table gives an overview of the results of the single project tasks and a status report about the completeness.

Table 32: Summary of the project outcomes

Description of the task	***Outcome***	***State***
Development of a useful design for the new bags	**Multiple bags option** **1x Inner bag + 1x Outer bag** **Inner bag**: thin case material, stretchable, easy to cut it open **Outer bag**: Durable, strong enough to carry the amount of wet grain, lifting tools attached	Solution completely elaborated
Selection of a suitable material which meets the requirements	**Requirements:** Cheap raw material, resistance against weak acids, established recycling process, meets the technical requirements of the inner bag and the outer bag Material family: Thermoplastics **Outer bag**: **Polypropylene PP** **Inner bag**: **Polyethylene PE**	Solution completely elaborated
Selection of a suitable waste handling option	**Outer bag**: **Reuse + Downcycling/Recycling** **Inner bag**: **Downcycling**	Solution for inner bag elaborated Solution outer bag partially elaborated

Description of the task	*Outcome*	*State*
Examination of the commercial value of recycled waste	Prizes for the plastic waste depend on its purity degree. **Outer bag**: Big bag layers → granulate → **chair** **Inner bag**: Inner bag → granulate → **trash bag**	Solution partially elaborated
Research on purity degrees and the required cleaning technology	**No laws or regulations, which describe the purity degree.** **The purity degree is a matter of negotiation** between the waste producer and the waste collecting company or recycling company. **Cleaning process is a crucial step in recycling plastic waste.** **Machines for the recycling comply with industrial standards** and are complex and expensive	Solution partially elaborated
Suitability analysis about edible plastics	Various approaches to create edible packaging. **Technology is young and not approved.** Probably the same problems as with biodegradable plastics regarding the poor resistance against weak acids.	Solution completely elaborated

As it can be seen in the table, some solutions are only partially elaborated. This does not mean that the task is not fulfilled. The project team worked for four months on this project, which has the character of a basic research work, and elaborated solutions and found answers for all the tasks and questions. However, the solutions have sometimes a basic character and need further researches to work them out in detail. Only then the solutions are useful for the future implementation of the project 'Wet Grain in Package'. The project team recommends the following actions to improve the solutions of the tasks, which are highlighted in a red color:

- *Selection of a suitable waste handling option (regarding the outer bag)*

  Recommended action: Contact with a manufacturer of big bags and a recycling company to get more information how often the bags can be reused and what can be done with the damaged big bags regarding recycling and downcycling.

- *Examination of the commercial value of recycled waste*

  Recommended action: Contact with a recycling company and researches to get the information how much plastic waste is needed to create a commercial value to determine the profit out of the recycling or downcycling process.

- *Research on purity degrees and the required cleaning technology*

  Recommended action: Contact with a recycling company or an expert out of the plastic industry to get information about purity degrees and technology in the project region.

5.4.2 Evaluation of the project outcomes by a comparison

A comparison of the two technologies help to assess whether the measures, which were developed for the new wet grain storage technique by the project team, were useful or not. In Figure 66 these measures are divided into 'Functional Options', 'Waste Reducing Measures' and 'Waste Handling Techniques'.

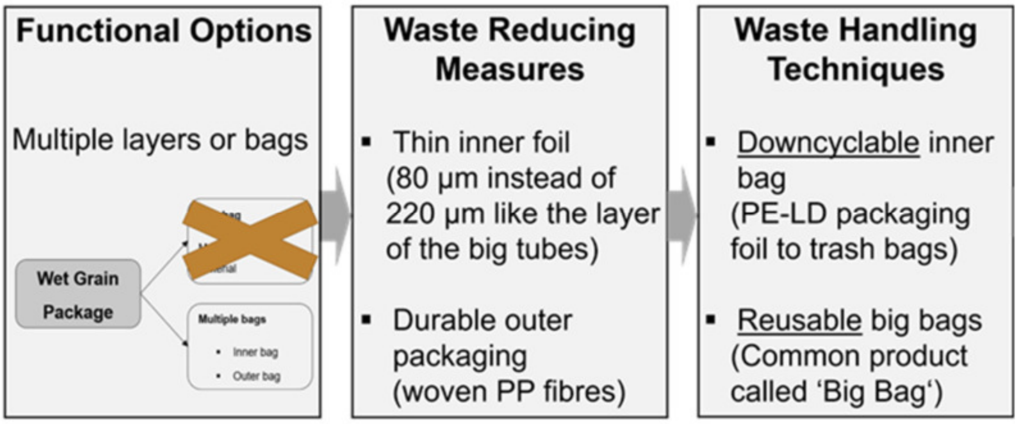


Figure 66: Summary of the results of the project work

The '**Functional Options**' include the decision to use multiple layers instead of one layer as in the big tube technology. In this way, it is possible to fulfill the requirements of the new flexible and mobile wet grain bags. In addition, it is easier to recycle the bags, which is a big disadvantage of the big tubes technology, which works with a foil of three layers. These three layers have different colors and are attached to each other. This issue can make it difficult to recycle the foil, if there are requirements regarding the color. Due to these facts, the new wet grain packages are advantageous.

Another interesting aspect are the '**Waste Reducing Measures**'. The new storage units should be environmental friendly. A first crucial step is to avoid wastage and to reduce or improve materials in the product design. In the case of the new wet grain packages, the team suggested to use a thin inner foil and a durable outer packaging. The outer packaging should be strong enough for the wet grain loading and durable for a longer period to have the possibility of reusing it. The inner foil cannot be reused and that is why it needs to be as thin as possible. Researches showed that a thickness of 80 Micrometers should be enough for the inner bag to avoid any material cracks through the load of the wet grain. Further tests are recommended to examine whether a lower thickness is possible or not. Big tubes have a material thickness of approximately 220 Micrometers. A comparison of these two numbers is worthless, because the volume of the packages needs to be included in this consideration to make statements about the amount of waste. The project team worked with the unit of measurement 'waste factor'. This factor is calculated by dividing the weight of the plastic through the volume of packed grain. The unit is kilogram per cubic meter. (kg/m^3) The formula is shown below:

$$\frac{Plastic\ weight}{Volume\ packed\ grain} = waste\ factor\ (\frac{kg}{m^3})$$

Table 33 shows the parameters, which are used to compare the amount of waste, which arises by using each of these two storage technologies. There is only the one limitation that the big tubes technology is compared with the inner bag of the new grain storage and not the whole product. This is a necessary simplification, because the outer bag can be used several times. The exact reuse factor is difficult to determine. In this comparison, the project team decided to concentrate on the amount of waste, which arises using the inner foil to get a first feeling in which direction this technology goes.

Table 33: Characteristics of the big tube storing technology and the new wet grain packaging

	Big tubes technology	Wet Grain Package 1 m^3 (inner bag)	Wet Grain Package 282 m^3 (inner bag)
Volume (m^3)	282	1	282
Weight plastic (kg)	123	0,456	128,6
Waste factor (kg/m^3)	0,436	0,456	0,456

The table shows that the amount of waste is higher for the new storage technology than for the method of big tubes storing. This difference will increase, if the amount of used outer bags is also taken in consideration. The following graph shows the waste factor.

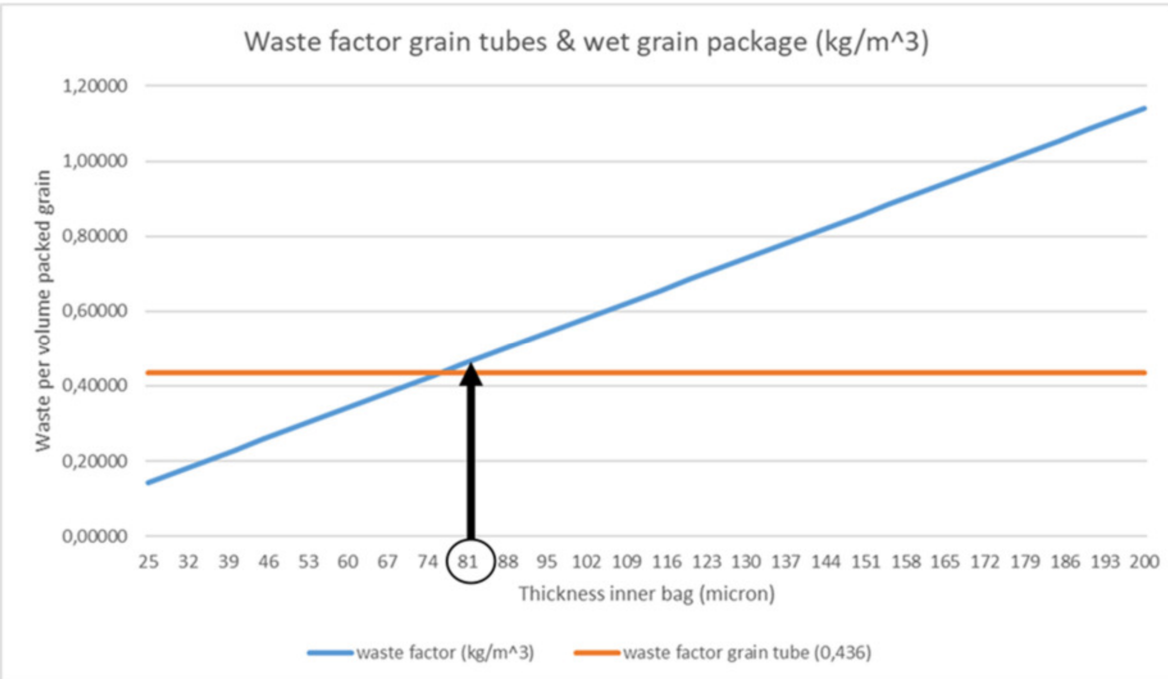


Figure 67: Waste factor for the big tubes technology and the new wet grain packages

The constant orange line in Figure 67 shows the waste factor for the big tubes technology, whereas the rising blue line shows the waste factor for the new wet grain in packages. The x-axis shows increasing material thicknesses and is only relevant for the blue line of the new wet grain packages. The selected thickness for the inner bag is highlighted and visualizes the result of the calculation in Table 33. This graph shows that the material thickness needs to be less than 74 Micrometers to gain an advantage regarding the amount of waste. The project team estimated that, in case that the Polypropylene outer bag is taken in consideration, the material thickness for the inner bag must be less than 50 Micrometers to have the same amount of waste as for the big tubes technology. If such low material thicknesses are possible for the inner bag, should be analyzed in practical tests. In comparison to the big tubes technology, the new wet grain packages create more waste. Nevertheless, the project participants, for example Hans Arvidsson, expected a higher difference and were positively surprised. The project does not only have the economical friendliness as a goal, but also the flexibility of the wet grain storage. Therefore, it is unavoidable that the new storage technique with its small volume creates more waste.

A further step to avoid waste is the choice of suitable '**Waste Handling Techniques**'. For the outer bags two waste handling techniques should be used. At first, the bags are reused several times till they are damaged. As a second step in their product lifecycle, the outer bags go into a recycling or downcycling process. The inner bag will be downcycled immediately after its usage. The foils can be easily recycled, because it is almost virgin material, which is only dirty by the wet grain loading. In contrast, the foils of the big tube technology are destroyed by the long impact time of the weather. For example, the sunlight or freezing temperatures destroy the polymers. This makes it difficult to get a recycled product of a high quality out of this material. The short lifecycles of the new wet grain packages are a big advantage compared with the big tubes technology.

Recapitulated, the new technology has enough advantages to compete against the big tube technology.

However, the amount of waste is higher than for the big tubes technology and this makes efficient waste management strategies necessary. The development of own strategies for the project region will be shown in the following chapter.

5.5 Development of waste management strategies

A sustainable handling of waste and reducing measures require a management strategy. Individuals do not have the potential to take efficient actions, but an organized group can collect significant amounts of waste to recycle it properly. This chapter looks on the plastic waste in the agricultural sector in general and analyses other waste management systems in foreign countries. Out of the insights, the project team developed own waste management strategies for the project region Ostrobothnia.

5.5.1 Plastic waste in the agricultural sector

The usage of plastic products in the agricultural sector is widespread. Whether for packaging the hay or the grass in the well-known 'moose eggs'. plastics can be found in various fields of application:

- Silo bales
- Covering foils for protection
- Packaging for fodder
- Acid cans
- Packaging of pesticides
- Big bags for transportation

Figure 68: Photography of a farm near Vaasa showing silo bales and a pile of rubbish

Figure 68 shows an example how farms use and handle the plastic. The photo was taken during a visit of a farm near Vaasa. In the background the storing process of wet grain in big tubes can be seen. On the right side is a typical example how the farmers use plastic. It is used for silo bales. On the left side is a pile of rubbish, which is a possible scenario on farms how they deal with the plastic waste. There is no waste management system especially for agricultural plastic waste implemented in the project region. Currently, the most common way to handle this waste is the transport to landfill sites or to waste incineration plants. To face the new world environmental challenges, the recycling is more and more adopted. Indeed, this technique has the advantage to give a second life, a new utility to a product and this is more environmental friendly.

Nowadays, solutions exist to recycle most of this plastic waste that is produced by the agricultural sector. Researches showed that some European countries, like France, Germany and Sweden, already have programs that reduce these amounts of waste.

5.5.2 Analysis of waste management systems in foreign countries

Researches and a meeting with Hans Arvidsson showed that there are three popular waste management systems. This chapter gives a description of each system in detail and a conclusion with suggestions for the development of own waste management strategies for the project region.

5.5.2.1 Canada 'Ontario Waste Management Association (OWMA)'

A region in Canada called Ontario made their own program to reduce the plastic waste in the agricultural sector. A partnership between 'product manufacturer', 'the provincial government', 'municipal government', 'retailers', 'farmers and waste management service providers' make it possible that plastic products used in the agricultural sector are safely and responsibly disposed of or recycled.

Figure 69: Plastic waste

If the plastic should be recycled, a working system that collects, sots and reprocesses the plastic must be invented.

The tasks of the farmers are collecting, pre-washing and separating the different plastics and bulking these plastics into small square balers. There are already machines that can make small square balers, so a farmer can use the same machine for this as when the farmer makes hay balers.

For Reprocessing, the plastic must be cleaned before it will be recycled. Most of the plastic waste is converted into pellets for film or formed into products like plastic cups and picture frames. The plastics need to be inspected for contamination. If a plastic is usable or not depends on the level of contamination. Contamination includes dirt, acids, glue tape and ultraviolet light degradation. After the inspection, the plastics are chopped into small parts and then fed into an extruder. It depends on the type of plastic if the plastic is directly formed into a product or first into pellets as a raw material for further processes.

5.5.2.2 Germany 'ERDE'

Figure 70: German Project © ERDE

ERDE is a recovery concept for crop plastic in Germany. This program is mainly used for the agricultural sector. Famers that have used the plastic, can dispose the plastic waste at an ERDE collection point. Four big companies are working together and have developed the concept that will recover the plastic waste in the agricultural sector. These four companies are 'Manuli Stretch Deutschland GmbH', 'Polifilm Extrusion GmbH', 'RKW Agri GmbH & Co. KG' and 'Trioplast Folienvertrieb GmbH' and are working together under the name 'IK Industrievereinigung Kunststoffverpackungen e.V.'. These companies took the initiative to protect the environment. The companies do not want to give responsibility to the customer of the plastic packaging but rather organize and promote the recycling program.

The farmers can easily shed their plastic waste at one of the ERDE collection point. There are some criteria when a farmer wants to shed his plastic waste at an ERDE collection point. The farmers must divide the plastic waste in two groups. Group 1: Silage sheets, under layer films and silo tubes. Group 2: Silage stretch films a Net replacement films. After the separation, the farmer needs to clean the plastic waste and the dirt on the plastic waste must be swept of. No foreign products can be mixed up in the films. Iron, wood and tires are not allowed to mix up in the plastic waste.

After the collection, the plastic waste will be recycled. In a manufacture, the plastic waste will be chopped, washed and melted down and extruded into regrind. The regrind can be for making new plastic products like plastic bags or a plastic picture frames.

Every company that collects plastic can become member of this organization. 'IK Industrievereingung Kunststoffverpackungen e.V' is also cooperating with 'RIGK'. 'RIGK' is another organization that focuses on reducing plastic waste. When ERDE is not able to collect a type of plastic it can be returned to the 'RIGK' service.

5.5.2.3 Sweden 'SvepRetur'

SvepRetur or 'Svensk Ensilageplast Retur AB' is a company which is responsible for collecting large volumes of used plastic in the agricultural sector. The industry-owned materials company works on a non-profit basis and ensures that the collected agricultural plastic is recycled in an environmentally adapted manner.

Figure 71: Collecting agricultural waste © SvepRetur

The first step of this program is to divide the different forms of plastic on the farm. This means that PP and PE cannot be sorted in the same category and need to be separated from each other. For hand in, the plastic should be as dry and clean as possible. In the case of 'Wet Grain in Package', it cannot contain any objects, such as iron, soil, sand or old grain. If the farmer handles the plastic correctly and cleans the inner bags properly, the recycle degree will be higher.

For the 'Korntainer' team, it is important to look at how the plastic is sorted into categories with a close look on how SvepRetur handles the big bag waste. For the sorting of big bags, is it not possible to place any other plastic in the bag. It is only possible to place products with the same material in these bags.

The farmer collects and transports the waste to one of the many collecting points where the plastic can be deposited. The program collects 70% of the plastics used in the agricultural sector, 30% of the gathered plastic should be recycled into new plastic products and the remaining plastic goes to waste incineration plants for energy recovering purposes. The energy is used for heating and electricity.

5.5.2.4 Conclusion with important information for the own project

It is good to see that a lot of companies and organizations are investing in programs that will ensure the protection of the environment. These programs started small, but they developed in a short period. The best thing to see is that the producers of the agricultural plastics are pro-active to reduce the plastic waste in the agricultural sector.

In case of the project 'Wet Grain in Package', it would be a good idea to develop a program that contains parts of the programs they are using in other countries.

Some suggestions for requirements regarding the development of own waste management strategies are listed on the next page.

Basic program requirements:

- Plastic waste needs to be divided in different groups.
- The farmer must clean the plastic waste.
- A transport service can go around farms and take the plastic waste to a fabric.
- There are collecting point around the farms.
- The producer of the packaging is responsible for the packaging on the market. The producer must finance the collecting, sorting and recycling system

5.5.3 Development of own waste management strategies

This chapter gives short descriptions of the own developed waste management strategies. These strategies also include a description of the underlying assumptions how the trading system for the new wet grain packages works.

The project itself dealt with the question how to handle the waste, which arises from the use of the new wet grain storing technology. Though the packaging machinery for the wet grain in the flexible storage units has not been developed at the end of this project of the team 'Korntainer'. The same occurred to the development of the trading system. On this account, the team also developed broadly the trading system to be able to analyze various scenarios for the waste management systems.

5.5.3.1 Strategy 1

Strategy 1 is based on the structure of the big tube storing process, which is already approved in the project region. In this strategy, the entrepreneur is the backbone of the trading system. In an internet marketplace the farmers can book the service of the entrepreneur. He brings his own equipment and machines to the farm and fills the wet grain in the new package units. Extra big bags of wet grain, which are not needed on the farm, are transported to the warehouse of the entrepreneur. The farmer gets a previous defined prize for his wet grain packages of the entrepreneur. The prize is created by the supply and demand on the internet marketplace. Farmers, who need wet grain, can buy these packages from the entrepreneur, who brings them to the customer.

Plastic waste out of the use of the new storing technology is collected by the same entrepreneur. He washes and sorts the inner bags and inspects the outer bags on any damages. If he collected a significant amount of plastic, he will transport the plastic to a recycling company and get the profit out of this sale.

This strategy does not include the collection of any other waste than the waste which arises from the use of the new wet grain packages.

Though it is easily possible to expand this strategy to collect all the waste on the farms, which take part in the wet grain trading system.

5.5.3.2 Strategy 2

Strategy 2 is based on the same principle as the method which is been using in Sweden for collecting the agricultural waste, but this strategy includes a start-up of a trading system between farmers.

For this strategy, it is important to know who the responsible is for the plastic waste in the agricultural sector. In this case, the producer of the inner foil of the big bag packaging is the end responsible for what happens with the plastic waste. The producer is end responsible for collecting the plastic waste and responsible for the recycling process.

Figure 72: Plastic bale © tammodule.

Introducing the 'Wet Grain in Package' to the farmers is challenging. Most farmers are satisfied by the old way of packaging. Using entrepreneurs to introduce the new packaging could be one solution. They could also be an important intermediary to start a trading system between the farmers. The entrepreneurs are the one who must change their machinery to fill the big bags. But at the end, the farmers will trade the bags with each other without any intermediary person. The farmers decide by themselves which price the big bags will get and how the bags will be transported from farm to farm.

In this strategy, the farmer has also a few responsibilities. The end responsible expects clean and dry plastic from the farmers and it should be combined in a plastic bale as shown in Figure 72. For the cleaning part, it is important that there is no dirt or old wet grain on the plastic waste. The plastic needs to be separated from each other and divided into different groups. For example, PE is one group, and cannot be mixed with PVC or another plastic. In addition, other materials as iron and tires cannot be collected with the plastic waste.

The wrapped bales can be collected at a collection point in the area. From there the plastic bales can be transported to the recycling manufactory. Plastic waste, which cannot be recycled, can be transported to waste incineration plants for energy recovery purposes.

5.5.3.3 Strategy 3

Strategy 3 is closer to the French system for the collection of the waste, but it keeps the same grain package trading system principle than described in strategy 2.

Contrary to strategy 2, the producer of the wet grain package is just a seller in this scenario and does not have any other role. The collection of the plastic waste is both the responsibility of the farmer and the recycling organization.

Figure 73 : Fold instructions for farmer © Adivalor

On the one side, farmers must take care not to mix different type of plastics (PE, PP), because, as they have different properties (melting/ignition point, density, resistance), they would damage the extruder in the recycling process. Sorting the different materials is the very first step that farmers need to respect. Then they must wash the plastic films. This is just a basic washing to remove all the remaining dust, sand or other gravel. The cleanest it can be, the better it is. Furthermore, the farmers must fold them, roll it into a ball to make it more compact, as shown in the Figure 73. When it is done, it is more transportable, and then farmers can easily bring them to a collect point.

When they have brought their waste to a collection point, which are put in place by the organization in charge to recycle the waste, the job of the farmers is done.

It is recommended to take as an example for the development of these collection point structure the existing programs in countries, like France and Germany. There is the organization of waste collection points already well developed. Many collection points exist so that farmers do not have to transport the plastic wastes over long distances.

When there is a sufficient quantity, the waste is transported to the recycling center, where they are compacted into balls (see Figure 74), to be more easily storable.

The interesting part of this strategy is that when the farmers are in the collection point, they can receive a certificate that confirms the amount of waste they bring. With this certificate they can receive later money from the recycling organization, which has transformed their waste into a profitable product.

Figure 74 : Waste collection point © Adivalor

In the case that farmers have additional grain packages, they can exchange them with other farmers, who needs it. This internal network might be created by the recycling organization.

An illustration that summarizes the principles of this strategy, can be found in the appendix.

5.5.4 Evaluation of the waste management strategies

The three waste management strategies have various approaches how the handling of the waste can be done. Figure 75 summarizes the advantages and disadvantages of the strategies.

Strategy 1

- No collection points, because the entrepreneur collects the PE-LD and PP waste
- Easy to implement
- It is limited to the packaging materials of the new system

Strategy 2

- Need of collection points
- Collection of all the waste of the agricultural sector
- Producer of the packaging needs to pay for the collection points

Strategy 3

- Need of collection points
- Membership in an association with annual payments
- Certificates for clean amount of waste to create a commercial value

Figure 75: Results of the evaluation of the various waste management strategies

As the summary shows, strategy 1 is the easiest option regarding the implementation of the waste management system. The entrepreneur is the one, who executes the waste handling and therefore, the waste management system is linked to the new developed wet grain trading system. There are no collection points needed, what lowers the investment costs for the implementation of the new wet grain storing technique in the project region. These are the advantages of this technology. The biggest disadvantage is the dependence of this system on the entrepreneur. If there is no person in the region, who wants to do this job, the waste management system cannot exist. The system is also limited to the collection of the waste which arises from the use of the new grain storage technique. It is easy to expand the collection activities of the entrepreneur to other plastics than Polypropylene and Polyethylene. However, it can be that the entrepreneur is not interested in this work.

Strategy 2 and strategy 3 are facing this issue by using collection points, which bring the advantage that the farmers can collect and transport all the plastic waste from their farms to the waste collection. In this way, the farmers can avoid fees for the waste disposal (in case of strategy 2) or even earn money by trading certificates with the recycling company (in case of strategy 3). These strategies have the disadvantage that the investment costs to build up the waste collection points are high. These costs will even increase for the finnish project region, because the density of farms is low, which means more collection points.

The project team recommends using strategy 1 at the beginning of the implementation of the new wet grain storage technique, because this option has low costs and smaller risks than the other two strategies.

5.6 Monitoring and Controlling

The monitoring & controlling was the most important task for the team manager in this research project. Time restrictions, the unfamiliar surroundings and the research project with its huge amount of data were great challenges for the project management. But the management could handle these up-coming issues and therefore, the project was precious for the main project 'Wet Grain Package'.

To measure the progress of the work, the team agreed to use the **E**arned **V**alue **A**nalysis (EAV-analysis). This tool replied to the question 'Did the project deliver value to the business?' by comparing the current value of the work with the planned value and the actual costs. It is not possible to measure quality, but the tool helped to visualize the past and the current work status and, in addition, predicted the future performance of the project by using statistical techniques. The Earned Value Analysis integrates the data of the scope, the schedule and, if required, the costs of a project. A further advantage of this tool was the possibility to use it as a source of information for the stakeholders. They could see the performance of the project in one document or one diagram. The following Figure 76 shows an extract of the data, which was used for the EVA-analysis. The main work packages are listed together with the related resources of workers and the work progress as well as the costs per task.

Work Package:	WEEK 15 (12/11 - 12/17)												
	H. Bonnafous	Hours	Work Progress (%)	M. Haimerl	Hours	Work Progress (%)	G. Houtman	Hours	Work Progress (%)	J. van Dreumel	Hours	Work Progress (%)	Costs
Strengthsfinder-Workshops & Teambuilding													-
Projectmanagement													-
English Academic Writing & Cross-Cultural Comm.													-
Survival Swedish													-
Project Work EPS													
Basic Research to get familiar with a field of research													-
Weekly meetings with the supervisor	H	2	100%	M	2	100%	G	2	100%	J	2	100%	180,00
Project Management - Definition Phase													-
Project Management - Initiation Phase													-
Project Management - Planning Phase													-
Project Management - Monitoring & Controlling													-
Public Relations (e.g. Website)													-
Visit of companies/farms or meeting with experts													-
Presentation of the work progress (Mid-Term/Final Report)	H	8	100%	M	6	100%	G	8	100%	J	8	100%	667,50
Production of the research documentation (report)	H	8	100%	M	25	100%	G	8	100%	J	8	100%	1.166,25
Research work "Comparison of storing techniques"													-
Research work "Plastic waste in the agriculture sector"													-
Research work "Reducing waste in the agriculture sector"													-
Research work "Wet Grain Package - technology in detail"													-
Research work "Possibilities for the inner & outer bags after use"													-
Research work "Evaluation of existing and self-developed techniques"													-
Research work "Required purity degrees and cleaning technologies"													-
Research work "Edible plastics and their suitability for the inner foil"													-
Case Study "Evaluation of the investigated solutions by a farm model"													-
Project Closing	H	14	100%	M	10	100%	G	14	100%	J	14	100%	1.155,00
Undefined	H	16	100%	M	20	100%	G	16	100%	J	16	100%	1.545,00
		48,0			**63,0**			**48,0**			**48,0**		**4.713,75**
	207												

Figure 76: Extract of the data for the EVA-analysis

The research work did not contain any costs because of wages. It was a student project and the team members did not get any money for their work. But for the monitoring & controlling this fact was not taken into consideration, because the labor costs could mirror the time effort. Furthermore, the team got an insight into the cost structure of a professional project. The following Table 34 shows the imaginary wages of the project members. The wages are oriented on the German labor costs and the degree is the future position of the students.

Surname	**Name**	**Future Professional Degree**	**Gross Wage** (assumption: 160 hours/month)			
Hugo	Bonnafous	Bachelor of Engineering Mechanical Engineering	3.400	€/month	21,25	€/hour
Michael	Haimerl	M.B.A. & Master of Engineering Industrial Engineering	4.200	€/month	26,25	€/hour
Gijsbert	Houtman	Bachelor of Engineering Mechanical Engineering	3.400	€/month	21,25	€/hour
Jasper	van Dreumel	Bachelor of Engineering Mechanical Engineering	3.400	€/month	21,25	€/hour

Table 34: Imaginary wages of the project members

These wages are used in the following Earned Value Analysis. The following line graph shows the deviations between the actual costs and the planned value and the earned value.

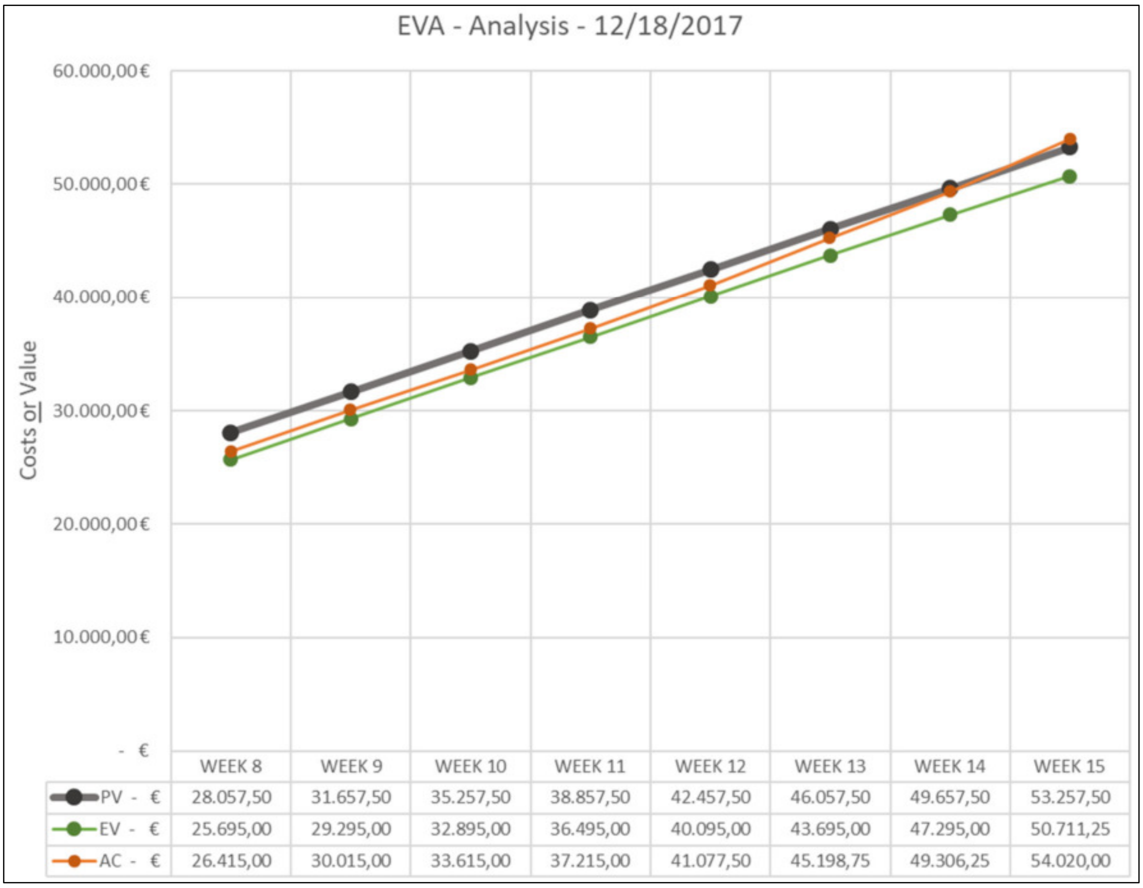


Figure 77: Earned Value Analysis – 10/24/2017

It is a fact that projects rarely go as planned and the Figure 77 shows also some deviations between the three graph lines for the date of December 18th.

Following the most important Indicators of the earned value analysis are listed.

EV = *50.711,25€*

PV = *53.257,50€*

AC = *54.020,00€*

Two further performance indicators, the schedule variance (SV) and the cost variance (CV) can be calculated by using the following formula:

SV = *Earned value - Planned value* = *50.711,25€ - 53.257,50€ = -2.546,25€*

CV = *Earned value – Actual costs* = *50.711,25€ - 54.020,00€ = -3.308,75€*

With the performance indicators schedule performance index (SPI) and cost performance index (CPI) it is possible to check if the project progress is in time and in budget. Since these figures are under one we are over schedule and budget.

SPI = *Earned value / Planned value* = *50.711,25€ / 53.257,50€ = 95,22 %*

CPI = *Earned value / Actual costs* = *50.711,25€ / 54.020,00€ = 93,87 %*

To make a statement concerning the future performance of the project it is necessary to calculate the estimated costs at completion (EAC) and the estimated duration at completion (EDAC) as well.

EAC = *Budget at completion / CPI* = *51.300,00€ / 0,9387 = 54.650,05€*

EDAC = *Duration at completion / SPI* = *106 days / 0,9522 = 111,3 days*

The team needed to work on the elaboration of the final report longer than expected and the elaboration of the case study was cancelled, and the focus was on the elaboration of the waste management strategies, which took longer than expected. That is why the costs increased by 3.350,05€ and the time increased by 6 days, which needed to be done in form of extra hours to finish the report to the final date.

6 Conclusion

The product ‘Wet Grain Package’ provides the costumer an easy usable, cheap and environmentally friendly solution to pack crimped grain. This product, consisting of two parts, is the optimal result after investigations about material, environmental impact and profit for the farmer.

Different ways of grain packaging are investigated to compare the advantages and disadvantages of each. The report shows why the wet grain package is a potential game-changer and how it competes with existing products.

With making use of the two parts system, the plastic usage of grain packaging is decreased tremendously. The outer bag is suitable for multiple reuses, this makes the inner bag the only regularly plastic waste source of the wet grain package.

The study showed that a normal farmer in Finland only creates approximately 57 kilograms of plastic waste every year by using the wet grain package.

Multiple end of life options for the plastic waste are compared and described. Downcycling is the most realistic option and the plastic waste has the highest value. To make downcycling possible a waste collecting program in the area where the wet grain package will be used is needed. These programs already exist in various countries. The report describes the programs and investigates which program is most suitable for the wet grain package waste.

The launch of the wet grain package will create a trade market of grain packages, but this is not fully investigated in this report because it was not part of the subproject. It is important to do a research on this subject to make sure there is a need for this kind of marketing system.

Another important research matter for the product are the costs. These should be relatively small to make the wet grain package as attractive as possible. The calculation investigates the price of the package by accounting the material and production costs. These fixed costs are completely defined in the report, but costs can differ when the quantity increases. Logistics costs decrease when more products are ordered. An investigation about the break-even point between the quantity and effort of the product is recommended to define the target audience between all the farms.

The research about the edible plastic is showing, that the technology is not developed enough for being used in the agricultural sector. The option already exists in the food industry, edible plastic made of seaweed, fruit shells or made of a milk protein called casein. These options reduce the plastic waste in the food industry but are not yet usable in the agricultural sector because of the lack of information. Is the edible packaging able to contain weak acids? What happens when there is a variation of temperature? These are just two questions which cannot be answered because there has been no research about it. A further research leads to a suitable edible plastic that can be used in the agricultural sector which will reduce a lot of plastic waste.

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Appendix

Appendix 1: List of all 34 strengths of the Gallup test and their description

Gallup Strengthsfinder - 34 strengths in comparison

Executing		Project team
Achiever	Focus on achieving a goal for the day; energized by achieving	Gijsbert
Arranger	Developing of new possibilities or new paths	Jasper
Belief	Dependable and stable in every situation; strong values in work	Michael
Consistency	Preference to develop a consistent environment with clear rules to ensure a secure work place for the others	Jasper
Deliberative	Preference to identify risks and develop measures to reduce them	
Discipline	Conscientious, attentive and persistent in the work	
Focus	Clear objectives; efficient in the work	Gijsbert
Responsibility	Psychological ownership for every given task; willingness to volunteer; hard working	Michael
Restorative	Energized by the process of solving new arised problems	Hugo

Influencing		Project team
Activator	Preference to take actions after a goal is set; learning out of mistakes	Gijsbert
Connectedness	Solidarity, team thinking, bridge builder	
Command	Not frightened by confrontation; honest with everyone; convinced of yourself	
Communication	Preference to be a moderator; eloquent and a good salesman	Michael
Competition	Setting of objectives by focusing on the competition with others	Gijsbert
Maximizer	Perfectionism in work	
Significance	Need to be admired as credible, professional and successful; pushing others to the same level	
Woo	"winning others over"; preference to meet new people and getting them to like you	

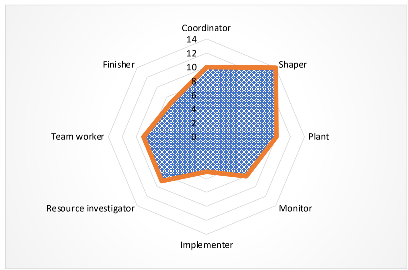
Relationship Building		Project team
Adaptability	Flexibility in every situation	
Developer	helping others to reach a higher work quality and quantity	Michael
Empathy	Hearing the unvoiced questions; helping other people to express themselves	Jasper
Harmony	harmony in a team; support and understanding of the others	Jasper
Includer	Preference to include people and make them feel part of the group	Jasper
Individualization	Focus on the differences between individuals; analyzing of each person's style and motivation	
Positivity	Motivating of others because of the positive attitude	
Relator	Preference to intensify and improve the work relationship with well-known persons	Hugo

Strategic Thinking		Project team
Analytical	Thoughts based on facts; searching for patterns	
Context	Searching for answers in the past for issues and problems in the future	
Futuristic	Following of visions of the future; creating own future scenarios	Gijsbert
Ideation	Interest in everything; collecting of information and knowledge	Michael; Hugo
Intellection	Preference to think intensively about issues	
Input	Preference to collect everything because everything is or might be interesting	Hugo
Learner	Preference to learn	Hugo
Self-Assurance	Self-Confidence; showing of security in every situation	
Strategic	Analyzing of various scenarios and the possibilities of them	

Appendix 2: Belbin test profile of the team

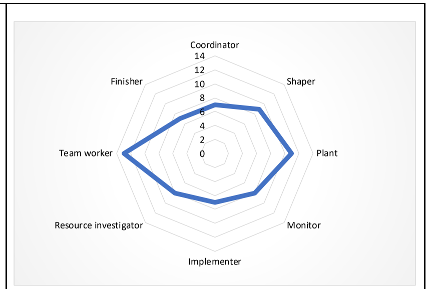
Gijsbert Houtman

	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	1	2	2	2	0	1	2	0
2	2	3	2	2	0	0	1	2
3	2	1	1	2	0	2	1	1
4	1	1	2	0	1	1	2	2
5	1	2	1	1	1	2	1	1
6	1	2	1	1	1	1	2	1
7	2	3	1	0	2	2	0	0
Total	**10**	**14**	**10**	**8**	**5**	**9**	**9**	**7**
	think				act			



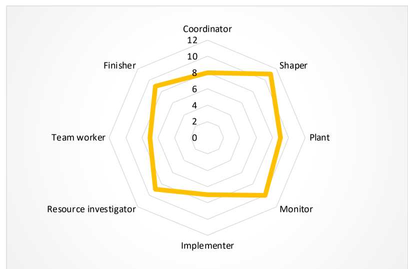
Hugo Bonnafous

	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	2	1	1	2	1	0	2	1
2	1	2	3	1	0	0	2	1
3	2	1	1	1	0	3	1	1
4	1	1	2	2	1	2	1	0
5	0	0	0	1	2	1	4	2
6	0	1	3	1	2	1	2	0
7	1	3	1	0	1	1	1	2
Total	**7**	**9**	**11**	**8**	**7**	**8**	**13**	**7**
	think				act			



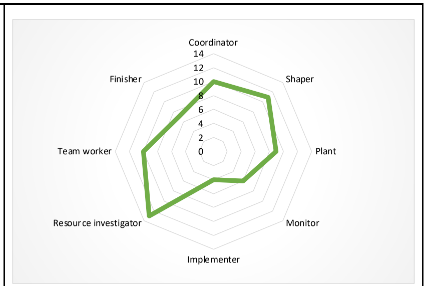
Jasper van Dreumel

	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	1	1	0	3	2	1	1	1
2	1	2	2	1	1	1	0	2
3	2	2	1	1	0	2	1	1
4	1	1	2	1	1	2	1	1
5	1	1	1	1	2	1	2	1
6	1	2	1	2	1	1	1	1
7	1	2	2	1	0	1	1	2
Total	**8**	**11**	**9**	**10**	**7**	**9**	**7**	**9**
	think				act			

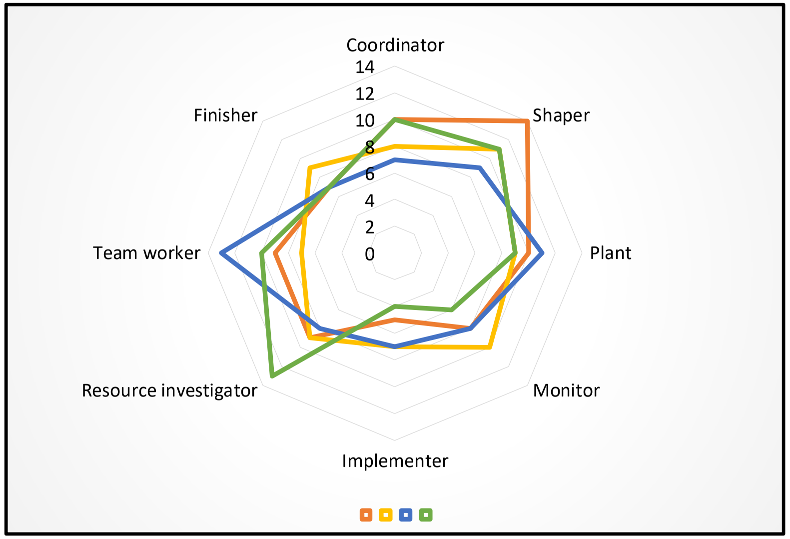


Michael Haimerl

	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
1	1	1	1	2	1	1	2	1
2	1	1	2	1	0	2	2	1
3	2	1	1	2	0	2	1	1
4	1	1	2	0	1	2	3	0
5	0	2	1	0	1	3	0	3
6	1	2	1	1	1	1	2	1
7	4	3	1	0	0	2	0	0
Total	**10**	**11**	**9**	**6**	**4**	**13**	**10**	**7**
	think				act			



Area of Orientation	*Strengths*	*Names* Hugo Bonnafous	Michael Haimerl	Gijsbert Houtman	Jasper van Dreumel
Communication orientation	Coordinator	7	10	10	8
	Team worker	13	10	9	7
	Resource Investigator	8	13	9	9
Knowledge orientation:	Plant	11	9	10	9
	Monitor	8	6	8	10
	Specialist	-	-	-	-
Activity orientation:	Shaper	9	11	14	11
	Implementer	7	4	5	7
	Finisher	7	7	7	9



Appendix 3: Fodder and its ingredients

Carbohydrates
Carbohydrates contain sugars and starches and will provide energy and heat. Consumed carbohydrates that are currently not necessary for the livestock, will be stored as fat.
Protein
Proteins are important for the grow and repair of the body. Hence protein food is feed to young and growing up animals.
Fats
Fats, just as carbohydrates, provides the body with energy and heat, but the energy value is two times higher than it is of the carbohydrates.

Appendix 4.1: Table of requirements 'outer foil' – Performance requirements

Performance requirements	
1PR	The outer bag has to protect the inner bag. One of the main goals is to protect the inner bag. Nowadays, there are a lot of farmers who have to deal with vandalism. These farmers find their big bags being cut open. An outer bag has the requirement to protect the inner bag of such a damage. Otherwise the grain would dry and then it could not be used anymore to feed the livestock.
2PR	The outer bag has to be transportable. The farmer collects the grain in these bags to feed the livestock. Nowadays, these big bags cannot be moved after they are filled with wet grain. Because of the new size of the bags, they can be transported to the farm and stored in a barn. This can be an advantage to deal with vandalism.
3PR	The material of the bag has at least a durability for a 4 or 5 times use. The outer bag is made for re-use. After every use, the outer bag needs to be checked for holes or cracks. If the bags are rejected, there is a possibility to recycle them or the material can be biodegradable.
4PR	The outer bag has a volume of 1 cubic meter. (LxWXH) 100x100x100 cm. For a good transportation, the bags need the same size as volume. For this exists an agreement, saying the volume of the bag is always the same.
5PR	When the outer bag is not being used, it has to be stored in an efficient way. When there is no need to use the bags, it needs to be stored. It depends on the material, that is used for the outer bag, how to store the outer bags
6PR	The logo of the company can be printed on the material of the outer bag. It is important for the company to show the customer what kind of product the company produce. It is an indication for other customers to see who has produced the bags. The farmer knows who he or she can contact, if there is a wish to use the bags for the own company.

Appendix 4.2: Table of requirements ‘outer foil’ – Functional requirements

Functional requirements	
1FR	One of the characteristics of the material of the outer bag is its high mechanical durability and strength. The material of the outer bag has to protect the inner bag. It needs to be strong, so it cannot be cut open as easy as the inner bag.
2FR	The outer bag has to carry the weight of a maximum of 1500 kg, when it gets lifted up from the ground. When the bags must be transported, they need to lift it up by a machine.
3FR	The outer bag has features, which allow it to open and close it. The outer bag needs to be filled with wet grain and also there needs to be a possibility to put an inner bag into the outer bag. There needs to be a feature that can close the outer bag when there is grain inside. When the grain needs to be fed to the livestock, it should easily be possible to open the bag.
4FR	The outer bag has a lower or the same stretch as the inner bag. If the outer bag has not a lower or the same stretch as the inner bag, it can be possible that the inner bag breaks or gets greater damages.
5FR	The outer bag might be able to get other materials attached to it. When there is a possibility to attach the inner bag to the outer bag, it might be possible to use it again. This requirement depends on the achievable purity degree of the inner bag.

Appendix 4.3: Table of requirements ‘outer foil’ – Manufacturing requirements

Manufacturing requirements	
1MR	The material of the bag has to be made by machines and in an efficient process. It is important that the bags are made by a machine. A machine does not make as many mistakes as humans. So, the outer bags are made the same way and will not be different compared to the other outer bags, which means a stable quality. Therefore, the outer bags will always have the same characteristics and the same structure.

Appendix 4.4: Table of requirements 'outer foil' – Safety and environment requirements

Safety and environment requirements	
1SR	The loops attached to the outer bag need to be secure. The weight of one bag is 1500 kg and this means on one loop works a force of 375* 10= 3.75 kN. The attachment of the loops needs to be secure, otherwise the attachment will break and the bag will fall on the ground.
2SR	The material of the outer bag has to be produced with as little carbon dioxide emissions as possible. When the bags are produced, there is a limit of producing carbon dioxide. The production has to be as efficient as possible.

Appendix 4.5: Table of requirements 'outer foil' – Wishes

Wishes	
1W	After the material no longer meets the requirements, it should be biodegradable. If there is an opportunity to make the outer bag from a biodegradable material, it will cost less money regarding the waste management costs. It is also better for the environment.
2W	After the material no longer meets the requirements, it must be recyclable. After the use of the outer bags, it is important to re-use the old material. This is possible, when there is a possibility to recycle the material.

Appendix 5: 'Harvest of wet grain' by ROmiLL

Harvest of wet grain

The main purpose of wet grain harvesting and preservation is to extend the storage life of grain and achieve cost savings (drying is usually much more expensive). However, there are also other reasons for it, for example reduced losses, enhanced utilisation of nutrients, more efficient use of harvesters during the harvest season, less dependence on weather conditions, a stable level of hygiene, increased intake of feed by animals, prevention of grain germination, protection against storage pests and the possibility of using feeds immediately after the harvest (enzymes are deactivated). Another reason for harvesting wet grain that cannot be omitted is that the resultant feed can be stored in close proximity to animal houses and other feeds used to prepare feed rations (without the need to involve any other company).

There are a few currently used methods of storing wet grains of maize and cereals in the Czech Republic. Wet grain can be stored whole ***without any physical treatment*** such as crumbling or crimping, using the following approaches:

1. **Protection in a CO_2 atmosphere** in specially adjusted tower silos. The stored material spontaneously produces carbon dioxide that pushes the air away, which starts the self-preservation process by inhibiting the growth of undesirable bacteria and fungi that need oxygen to survive. One disadvantage of this method is that it requires expensive airtight silos equipped with a withdrawing device with a sealing lid. Before the material can be used as feed, the grain has to be pre-treated – either by grinding or crimping.
2. **Preservation using propionic acid based agents**. In order to prevent degradation of grain during its storage, special chemical agents are applied, which contain not only propionic acid, but also some organic acids, antioxidants, and various agents that reduce the corrosiveness or improve the mechanical properties of feed by distributing and binding free water evenly. A chemical agent is applied in a worm conveyer, particularly in its input section. Grain is stored on heaps in sheds, or in wooden boxes. Before it is used for feeding, the grain must be broken up by grinding and crimping. This method is not 100% safe with regard to fungi.
3. **Preservation using soda lye**. Mixing grain with lye (preferably soda lye) and water results in a reaction in which the skin of grains cracks, grains swell and turn brown. In the case of maize this results in precipitation of starch. Grain treated with lye is stored for three months (or for six months in some cases).

Storage of wet whole grain without mechanical disruption is used to a lesser extent and is being gradually abandoned. This method of storage is being replaced by methods of split harvest and preservation of ***mechanically treated wet grains***.

The system of split harvest used to employ two methods: the LKS method used to prepare feeding mixtures for cattle, and the CCM method used in the case of monogastric animals – i.e. wet maize grain containing a portion of admixtures (stalks and bracts).
The LKS harvest uses picking threshers together with a special maize adapter, which only allows the harvesting of cobs with husks. Chopped cobs are stored and preserved in troughs or silage bags. The choice of maize adapter is very important as it determines how much of the above-ground part of the plant will enter production as an undesirable admixture and how big losses will be. Chemical or biological preservatives are added into the mass directly in the thresher or silage press. This method is being gradually abandoned due to the unstable quality of the mass. Feed stored in a pit or silage bag contains air, fungal spores and other micro-organisms that occur in stalks. This often causes fungal contamination and subsequent health problems in animals, although all principles of harvest have been observed.

Similar problems also occur in the case of the CCM method.

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The performance potential of maize grown for kernel is huge in comparison with cereals at the same nutritional level. The amount of ME (metabolised energy) per hectare, and the levels of nutrients in the respective feed, as well as costs, all depend on the farmer's decision on what type of harvest to choose.

METHOD OF HARVEST OF WET GRAIN USING ROMILL MACHINES

The split harvest of pure grains of cereals and maize is the most widespread, modern, reliable and therefore very economically advantageous method of storing grain grown for feeding purposes, and it is becoming increasingly popular in Europe.

Standard types of picking threshers are used that are known world-wide, such as Claas, John Deer, Masey Fergusson, New Holland etc. A number of companies (not only those that produce picking threshers) make maize and cereal adapters, for example Geringhoff , which is a well-known company in the Czech Republic.

The productivity of picking threshers is about 2.5 ha per hour, with losses not exceeding a level of 3%, depending on the moisture of the harvested mass. Maize kernel and cereal grain are harvested with a minimal content (in %) of admixtures, which ensures better safety in terms of health, and higher portions of both energy and dry matter in feed. This all results in increasing digestibility and energy utilisation in dairy cows.

To achieve the best quality with this method it is recommended that grain with a moisture content of 30 to 40% be harvested. In extremely dry summers, grain containing only 26% moisture was harvested after the moisture of the mass had been adjusted to 30% with water, while in the wet year of 2004 maize harvested with 47% moisture was reported, even in December. This all depended on the properties of the picking thresher to harvest mass at an acceptable level of loss, and accessibility of the respective field. Grain from the picking thresher's hopper may be passed in several possible ways, depending on the pattern of grinders and ROmiLL type of wet grain.

1. Crumbling of wet grain in the field

The **ROmiLL M2** mobile roller crumbler is designed for the harvest of wet grain. The M2 model is the most effective crumbler with an output of 30 to 40 t/hr. The machine is designed for work in fields close to picking threshers. The machine is connected like a trailer to a tractor with a minimum performance of 120 HP. It is driven by a Cardan shank at 1,000 revolutions/min. The fuel consumption of the tractor is approximately 0.5 l of oil per tonne of processed production. During work in fields, the ROmiLL M2 crumbler's hopper is filled by passing the grain from the picking thresher's hopper of 9 m^3. The picking thresher is emptied and then continues to work independently of the crumbler and other threshers. Thanks to its performance one ROmiLL M2 can successfully work together with two modern picking threshers during parallel harvest.

The ROmiLL crumbles grain to the desired texture – fine texture for pigs and coarse (crimped) texture for cattle. The texture can be changed simply and promptly without interrupting the operation of the machine.

The crumbled grain is preserved and transported by means of a system of stainless steel worm conveyers (part of the machine) to vehicles. The following operations take place on worm conveyers: controlled dispensing of a chemical (or biological) preservative, mixing with the crumbled material, and addition of water (if input material does not reach a minimum of 30% moisture). The machine brings four 200 l preservative-containing barrels attached to its chassis to fields and dispenses the preservative by means of a centrifugal pump.

The machine is equipped with a lifting device to manipulate with barrels containing preservative.

The stainless-steel lifting conveyer with a diameter of 250 mm is able to fill a wide range of vehicles (small tractor semi-trailers, trucks, high capacity semi-trailers of large vehicles and tractors). Vehicles then transport the crumbled, preserved wet grain of the required texture and moisture from the field to the place where it will be stored.

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The treated grain which was transported from the field is stored in anaerobic conditions (i.e. in the absence of air) such as silage troughs or silage plastic bags where biochemical fermentation processes take place similar to those occurring during silage of saccharide-containing fodder crops.

It is also possible to use the ROmiLL M2 crumbler directly at the farm and to fill by using a front loader. This is done from a heap of wet maize harvested independently of the work of the crumbler. This approach is used less often because of the necessity of transportation from the field to the crumbler, and from the crumbler to the place of storage. Maize should not be placed on heaps for more than 20 hours since it warms up, which may lead to degradation of feed.

A matter of interest is that the ROmiLL M2 machine can be used as a grinding mill for dry grain all year long. Most farms that have purchased this high-performance machine also use it for this purpose.

The wet treated grain is placed in **silage pits** and pressed. Air is removed by tractors or loaders running over the mass. Grain can be stored in silage troughs that were previously used for silage and haylage, or it may be stored in unused premises, which saves costs that would have to otherwise be spent for the construction of storage halls and silos. The surface of the mass is covered with PVC sheets and weighed down to prevent access to air. The width of the trough depends on daily consumption and the wall should not be exposed to the air for a long period of time. 3-4 weeks after harvest the grain stored can be used for the feeding of animals.

In other countries as well as in the Czech Republic, wet grain is often stored in **silage bags.** This is performed with the help of special pressing devices, which are particularly suitable for pressing maize silage, grass haylage, sugar-beet cuttings etc. The bag's diameter may be 2.4 m, 2.7 m, or 3 m, and the bag's length may reach up to 75 m. Bags with a diameter of 2.4 m and a length of 75 m can store at least 220 t of maize kernel. Thus, the utilisation of pressing devices will increase in the next agricultural production period.

Bags and troughs with grain of maize or cereals are usually stored in the proximity of other feeds – silage, haylage, meal etc. Another advantage of this technology is that during harvest the grain is ready for use in daily feed without further mechanical treatment, being preserved throughout the year. Feeding mechanisms (mixing feeding trucks, loaders) can simply withdraw the crumbled grain without further treatment, and prepare and mix the whole feed ration, saving on unnecessary transportation costs.

2. Crumbling of wet grain together with storage in a bag

The ROmiLL **CP 2** represents an innovation in the technology of wet grain harvesting. It is a mobile crumbler of wet grain, which also presses into a bag. The machine is designed to work on a farm where the bag is to be deposited. Wet maize or cereal grain with 30 to 40% moisture content is harvested by using picking threshers in fields.

Grain is transported from the field to the place of processing and storage in the usual way. The ROmiLL CP 2 receives cereals or maize from vehicles, crumbles them to the desired structure, dispenses a preservative at the required level, mixes the feed with a preservative, and places the product (by pressing it) in the bag so that the anaerobic environment in the bag where fermentation takes place is ensured.

The machine is mobile with a one-axle chassis, designed for being attached to a tractor with a minimum output of 160 HP. The ROmiLL CP 2 is equipped with two crumbling units, (similar to the ROmiLL M2) which crumble grain. The crumbling output is 30 to 40 t/hr. The grain is passed from vehicles to the feeding hopper via a worm conveyer. The crumbled material is sprayed with a preservative under the crumbling units by using a dispensing device equipped with a flow meter and 6 jets. The grain treated in this way is mixed by means of a worm conveyer and pressed directly to the bag. The machine, coupled with a tractor, moves by the effect of pressure in the bag and fills the bag with pressed grain. The pressing pressure is adjusted by using the machine's pneumatic brakes to ensure that the bag is aligned, filled and free of air. The bag has a diameter

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of 2 m and may be 40, 60, or 75 m long. Over a period of 5 hours as much as 140 t of the material can be placed into one bag without the need of expensive adjustment of premises, construction of silos or silage troughs etc. One major advantage is that by using one machine, one tractor, and one operating staff member you can perform several operations at an output level up to 40 t per hour, which also significantly decreases the costs of the harvest.
You can also use the ROmiLL CP 2 purely as a crumbler (without filling the bags) in the case of crumbled and preserved mass being emptied behind the machine and placed in a silage pit or undergoing further treatment. It is also possible to use the ROmiLL CP2 as a grinding mill for dry cereals throughout the year.

Preservation of wet grain

Preservation of wet grain in Europe is based on the use of biological or more frequently chemical preservatives, which ensure the preservation of quality feed particularly during warm months. Some farms use no preservatives for feed used in winter months (which cannot objectively be recommended), or use cheaper biological preservatives.
Chemical preservatives recommended by the company ROmiLL are agents based on the synergistic effect of formic and propionic acids. By their action they control the fermentation process and inhibit the growth of undesirable micro-organisms, thus decreasing the levels of harmful products arising from the metabolism of these micro-organisms (e.g. mycotoxins) in the material treated. Preservatives also contain other components, which provide antifungal and antibacterial effects (salts of organic acids) or significantly reduce corrosiveness as well as the typical odour of organic acids.
The amount of preservative to be added depends on the level of moisture in the harvested mass. Costs for the treatment of one tonne of material in the Czech Republic range between CZK 80 and 150, which is about EUR 2.5 – 5 per tonne of harvested mass. (The more water the material contains, the lower the amount of preservative is needed and the lower the costs for the treatment of one tonne of material will be). If grain has approximately 30% moisture, approximately 4 litres of chemical preservative are used per tonne of production. If the moisture content is close to 38%, the consumption of preservative is about 2.5 litres per tonne of production. ROmiLL machines are equipped with a dispensing device, which can be adjusted by a restriction valve and by changing the output of the pump. The operating staff can also check the correct adjustment of the flow rate meter.

Comparing economic indicators of the wet maize grain harvest method with the classic harvest of maize grain with drying

These economic indicators are reflected in approximate prices valid in the Czech Republic in 2004. The economics of the harvest are also affected by different factors such as transportation distances (which are specific for every farm), natural conditions and weather conditions during a harvest season. We assume average harvest conditions. We consider the harvest of an area of 100 hectares and compare the currently operated harvest by a method of drying with that based on crumbling of wet grain using the ROmiLL M2:

- Grain with 35% moisture content for storage in a trough, moisture for drying is 35% or 28%
- Yield of 10 t per hectare
- Transportation distance of 10 km: field to facility; 10 km: drying plant to facility
- Transportation by vehicle – 13 t tractor semi-trailers, price: EUR 1.5 per km
- Costs of drying: EUR 1.3 per tonne and percentage point of moisture
- Costs of chemical preservatives: EUR 4 per tonne of mass
- Costs of harvesting using a picking thresher: EUR 70 per ha
- Labour costs for the ROmiLL M2: EUR 6 per tonne of material
- Costs of grinding dry grain: EUR 1 per tonne

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It is clear that the economic effect of harvest technology cannot be rendered generally for every farm since specific and technical conditions as well as transportation distances also play very important roles.

	Drying of harvested grain with 35% moisture content **Drying**	**Drying of harvested grain with 28% moisture content Drying**	**Crumbling of wet grain with 30 - 40% moisture content**
Quantity of the mass harvested from 100 ha	**1,000 t**	**1,000 t**	**1,000 t**
Harvest by a picking thresher	EUR 7,000	EUR 7,000	EUR 7,000
Crumbling using ROmiLL M2			**EUR 6,000**
Preservatives + covering foils			EUR 4,300
Transportation from the field to a trough			EUR 2,310
Transportation from the field to a drying plant	EUR 2,310	EUR 2,310	-
Drying of maize to 14% moisture content	**EUR 27,300**	**EUR 18,200**	-
Transportation from the drying plant to a silo	EUR 2,310	EUR 2,310	-
Grinding of dry grain	EUR 1,000	EUR 1,000	-
Costs of the storage of dry grain	not calculated	not calculated	-
Increase in utilised energy of wet grain	-		+ not calculated
Costs of a 1 t harvest	**EUR 40**	**EUR 31**	**EUR 20**
Total per 1,000 t (approx. 100 ha)	**EUR 39,920**	**EUR 30,810**	**EUR 19,610**

Advantages of wet grain harvesting using ROmiLL:

- Harvest may proceed earlier, at higher levels of moisture and in less favourable weather conditions, without increasing the costs of harvesting
- Extension of harvest periods – better utilisation of picking threshers
- Nutritional value of wet ensiled feed processed by the ROmiLL system improves digestibility and utilisation of energy, enhancing the effectiveness of production
- It improves the health of dairy cows, reproduction factors, and utility parameters
- It optimises the starch ratio between the rumen and the small intestine, decreasing rumen acidosis
- The structure of the feed can be adjusted according to the required roughness, for cattle or monogastric animals
- Significant cost savings as compared with drying
- Productivity of up to 40 t per hour of complete harvest
- Decrease in demands on transportation during harvest
- Growing and harvesting of cereals and maize under less favourable climatic conditions
- Storage of grain without the necessity to construct expensive buildings

Appendix 6: 'Recycling process' for Polypropylene








Image 1 : Gather the same type plastic waste together and package them.

Image 2 : Transport them to recycling manufactory.

Image 3 : Divide them in small parts.

Image 4 : Densification of the shredded.

Image 5 : Product got after extrusion.

Image 6 : Cutting the strips im small pieces for the injection / molding.

Image 7 : Product got after injection / molding.

Image 8 : Finished products.

Appendix 7: 'Recycling process' for Polyethylene

Image 1: Fold the plastic films in ball.

Image 2: Transport them to a recycling manufactory.

Image 3: Cleaning.

Image 4: Grinding.

Image 5: Product got after the extrusion.

Image 6: Blowing.

Image 7: Manufacturing of the new plastic film.

Image 8: Finished product.

Appendix 8: Life cycle of recycled plastic film in the agricultural sector (© CPA)