Evaluation of the In-House Production of Insulation Material for Meal Kits

A Case Study at HelloFresh

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Abstract

Meal-kit boxes are considered a solution to reduce greenhouse gas emissions by reducing the food waste in the supply chain and households. Nevertheless, the consumers are concerned about the amount of packaging that comes with such a box, which is connected to higher carbon emissions than a grocery store meal. Thus, HelloFresh, a global market-leader in meal-kit boxes is driven to find more sustainable packaging solutions. The purpose of this study is to evaluate the impact of a cooling pouch produced in-house on the production process of a meal-kit producer and its environmental and economical impact. Two different in-house production methods were evaluated and compared against the pouch production from two different suppliers. The prototyping process and feasibility assessment showed that the first method, resulting in the same pouch type currently used at HelloFresh, shows a high grade of feasibility as it is an already existing concept on the market. Regarding the implementation of the second production alternative, a pouch made of compartments with paper-based insulation filling is complex, the results are inconclusive. The environmental and economical impact of the in-house production of insulation material for the meal-kit industry cannot be generalized and needs to be examined case by case. The greenhouse gas emissions caused by an insulation pouch depend on the origins of the raw material, transport modalities, the place of production and the local- and market-based emission factors. But the emissions might be lowered by the second production alternative that uses wastepaper for the insulation filling in compartments. Both production alternatives would result in a cost reduction. The study gives an indication that the in-house production of insulation pouches might generate lower emissions and create savings.

Keywords: in-house production, food packaging, insulation material, sustainability, paper-based

Executive Summary

In-house production of insulation material for the meal-kit industry

There is a global push for reducing food waste. A meal-kit box is one opportunity, but most consumers are concerned about the amount of packaging used in meal-kit boxes. Does in-house production of packaging materials reduce the carbon emissions? Not necessarily, but it might reduce the costs.

Global warming needs to be stopped, which can only be achieved by carbon neutrality. A highly important topic in the meal-kit industry is the carbon footprint of the packaging that is constantly worked on. A potential is seen in the in-house production of the insulation pouches associated with a reduction in emissions and costs and increase in flexibility. The pouches are used to transport chilled ingredients like dairy product with ice packs to keep them cool in the transportation process.

This project showed that there are different in-house production methods for insulation pouches conceivable. Rather simple methods, like the in-house sewing of a pouch, or more innovative and complex like the production of a down jacket-like pouch made of wastepaper. The first option would be rather easy to implement in the production and not much prior knowledge and testing is needed. On the other hand, the second option would require more testing like the assessment of the insulation properties and the development of the machinery. Both production methods show no signs of problems that condemn them to failure. A prototyping process was conducted to gain data for the analyses in this project.

Both methods were further analysed with regard to their impact on the environment and costs of the pouch. It cannot be generalised whether an in-house produced material is more sustainable than a purchased one. It needs to be checked for each individual case. The amount of emissions depends on different factors, e.g. the place of production and transportation routes, but more importantly, which type of emission factors that are considered. When looking at the energy mix of the country, both options would emit up to 75% more greenhouse gases. Considering the energy type purchased by the companies, the second method would emit 79% less. The emission numbers were assessed via a simplified CO_2-impact analysis, but not a

complete life cycle assessment. The results for the cost assessment are on the other hand clearer. It is most likely that the in-house production of insulation pouches would generate even up to 86% savings.

Overall, the second production method shows the highest potential, but it is also based on many assumptions and there might still be factors not considered that could change the numbers radically. Unfortunately, it was not possible to test the insulation properties. Thus, it is not clear whether this pouch type would isolate in the same way; however, this study can be used as an indicator, if might be worthwhile to consider an in-house production for the individual case and as a guide for further research. Further development should evaluate the insulation performance of the innovative production method and evaluate the production in different countries.

Acknowledgments

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Berlin, August 2020

Anne Bauer

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List of acronyms and abbreviations

3PL	Third party logistics
CIF	Cellulose Insulation Filling
CP	Cooling pouch
DACH	Germany, Austria and Switzerland
GLEC	Global Logistics Emissions Council
IA	Inventory Analysis
KrWG	Kreislaufwirtschaftsgesetz/Circular Economy Act
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
OPRL	On-pack recycling label
PnP staff	Pick-and-pack staff
SC	Supply chain
TTW	Tank-To-Wheel
VFFS	Vertical Form Fill Seal
WBCSD	World Business Council for Sustainable Development
WFD	Waste Framework Directive
WRI	World Resources Institute
WTT	Wheel-to-Tank
WTW	Well-to-Wheel

1 Introduction

This section presents the background of the report and identifies the problem, which underlies the thesis project. It explains the chosen case and defines research questions. Furthermore, it does provide an overview of the conducted case study method.

1.1 Background of Study & Problem Identification

The UN claims that every year 1.3 billion tonnes of food are wasted, but at the same time almost 2 billion people are hungry or undernourished. Therefore, one target of the 'UN Sustainable Development Goals' is to reduce the global food waste at consumer and retail level by half until 2030 and to 'reduce food losses along production and supply chains, including post-harvest losses' (United Nations, 2016). Heard et. al. (2019) showed that a good way of reducing the food waste is the use of meal kit boxes and that through the reduction of food waste, can carbon emissions be reduced by -0.86 kg CO_2e/meal. In general, meal kit boxes emit 33% less greenhouse gas emissions but often consumers are concerned about the higher amount of packaging in a meal kit box, which contributes with 0.17 kg CO_2e/meal more to the emissions than normal grocery store meals (Heard et. al., 2019). Therefore, the meal kit industry is constantly looking for possibilities to create a more sustainable packaging solution. Unfortunately, it is not always possible to reduce the amount of packaging. This may lead to an underpacking of the product, which negatively contributes to the greenhouse gas emissions through increased food waste (see Figure 1-1).

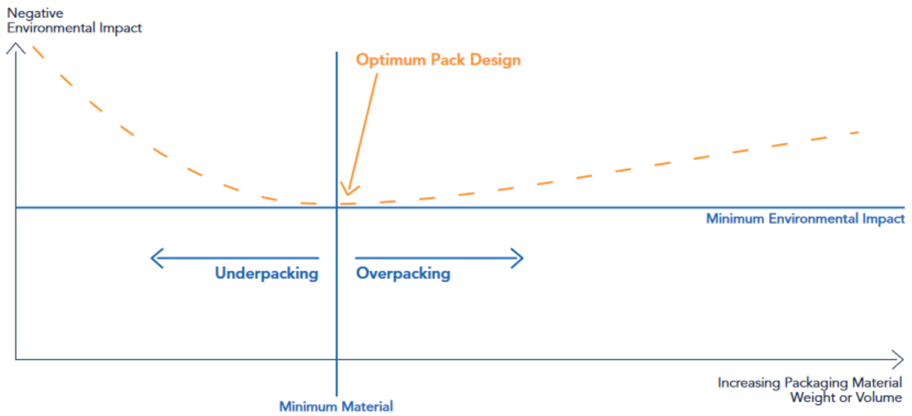

Figure 1-1: Optimum packaging design (EUROPEN, 2009).

Thus, other possibilities to reduce the environmental impact of the packaging from meal kit boxes should be found. This may be achieved by changing the production and purchase process of packaging material from a complete purchase to a (partly) in-house production. The transport of the raw material directly to the place of use instead of to another production and further transport of finished product might reduce the distances of transportation and therefore emitted CO_2. Also, the production of the product might emit less emissions when the local energy mix shows a higher percentage of renewable energy. To investigate the economical and environmental impact of the in-house production of packaging material, the insulation material for the meal kit boxes from HelloFresh was chosen. With every send out meal kit comes an insulation pouch for the cooled food products. While the primary packaging of the food products differs from recipe to recipe, the insulation pouch is the same for all meal kits and only differs in size and thickness. Thus, HelloFresh sees a high potential for an in-house production for the insulation material. The company switched recently from a plastic-based to a paper-based insulation pouch that they are purchasing as a finished product. Now they are considering producing paper-based insulation pouches in the distribution centres.

A study conducted by Accorsi et. al. (2015) shows the complexity of comparing different packaging production methods and the trade-offs between purchasing a preformed packaging and producing a packaging in-line. On an environmental perspective are the impacts by transportation facing the impacts by the production line. In this case two different materials were compared. Therefore, it is needed to evaluate the impacts and costs by different production methods of the same material. Another study by Białek (2014) showed that by packaging optimization done by the form, fill and seal method in comparison to purchasing pre-formed yoghurt cups can provide economic, social and environmental benefits. An example is the savings in the supply chain by reducing the number of needed vehicles.

1.2 Case Study

“A case study is an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.” (Farquhar, 2012)

To investigate the possibilities of an in-house production of insulation material for meal kits and its environmental and economical impact was a single case study chosen to be a suitable research method. This method facilitates a distinct understanding and in-depth view, which is needed for such a complex topic like sustainability. According to Farquahr’s (2012) guideline for case study research needs to be set a few research questions on which the following data collection is based. The data was then analysed and discussed.

1.2.1 The Case

The impact of an in-house production of insulation material for meal kits was studied within the context of the paper-based cooling pouch (CP) for the meal kits of HelloFresh SE. The company is globally leading in the meal kit industry, which was founded in 2011 (HelloFresh SE, 2020). They deliver boxes with ingredients and recipes for cooking a meal at home. These are delivered through a third-party logistics company (3PL). These boxes also contain perishable food which needs to be maintained under cool conditions. To keep the temperature low, perishable food, like meat and dairy, is packed together with ice packs in so-called cooling pouches. These pouches that were recently switched from plastic material to paper-based material for the DACH countries and Sweden and are aimed to be implemented in the UK. HelloFresh is determined to make the supply chain (SC) more sustainable (Richter, 2020). Therefore, the company was searching for possibilities to design the SC more environmentally friendly. As a contribution to achieve this aim was seen in the in-house production of the paper-based cooling pouch.

1.2.2 Research Questions & Objectives

This report aims to determine possibilities of an in-house production of insulation material in the meal-kit industry and its environmental and economical impact. Figure 1-2 shows the schematic overview of the overall case study approach. The first step of a case study is to formulate research questions on which the case study research is based. The first research question approaches the possibilities of the in-house production.

RQ1: What is the impact of an in-house cooling pouch production on the production process at HelloFresh?

To answer the first research question the following objectives have been set:

- To develop a deep understanding of the production process of insulation material
- To assess the characteristics and specifications of insulation materials for the meal kit industry
- To identify alternative production methods for insulation materials and evaluate the methods
- To determine the feasibility of an integration in HelloFresh's meal kit production line

Consecutively the results of the first question are the following research questions approaching the impact of the production. The two research questions are based on the two pillars of sustainability – the environmental and the economic sustainability.

RQ2: How is the environmental impact of an in-house produced cooling pouch compared to a purchased cooling pouch?

RQ3: How is the economical impact of an in-house produced cooling pouch compared to a purchased cooling pouch?

To facilitate the research, the two research questions were investigated separately instead of one question asking after the sustainability of the production. Afterwards both analyses were compared in a holistic view.

To answer the research questions a set of the following objectives have been set:

- To collect data about CO_2-emissions and energy usage in the following stages of the pouch life cycle
    - Raw material
    - Production
    - Logistics
- To assess the investment and operational costs of an in-house production process
- To give a justified recommendation for the most sustainable production method

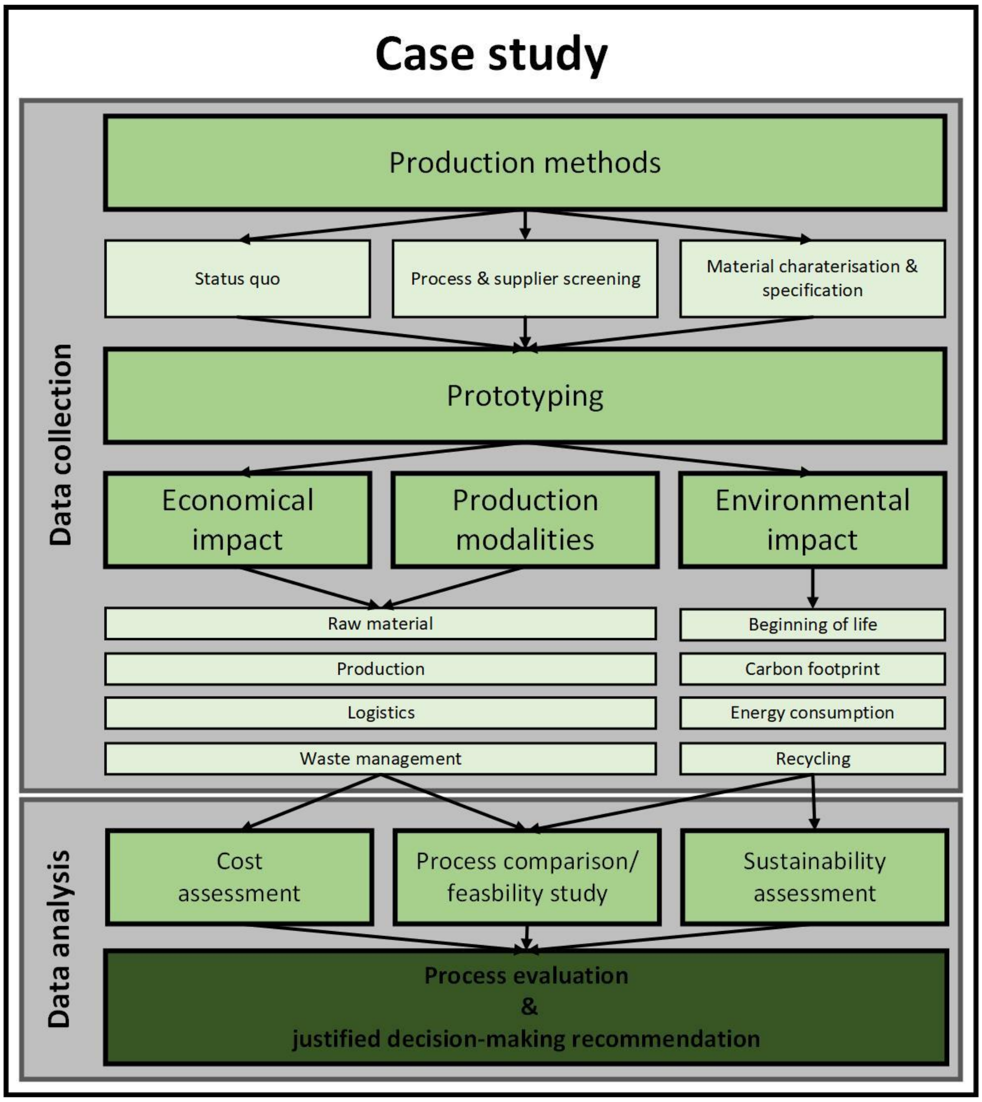

Figure 1-2: Schematic overview for overall study approach.

1.2.3 Delimitations

To reduce the complexity of the case study a few system boundaries were chosen. The work was focusing on paper-based material and was disregarding other materials like biodegradable plastics. As the supply chain and logistics are similar in the DACH countries, the UK and Sweden, and they have already implemented the paper pouch partially. The research was restricted to these countries and the main research was done on the German market. The life cycle and cost assessment are including the most important factors but are not detailed in depth assessment. Due to the pandemic it was not possible to access the international test laboratory and test the insulation properties of the different solutions. Therefore, it was assumed they are performing in the same way.

2 Theoretical framework

This chapter describes the theoretical framework of this case study. It explains the packaging system of the meal kit boxes, the stakeholders involved in the supply chain and the packing process of the boxes. To give a better understanding for the required properties of the cooling pouch are the thermal properties and the waste management clarified as well.

2.1 Packaging system

A packaging system consists of three different levels, which are interrelated. The first level is the primary packaging, which is in direct contact with the product. The secondary packaging is the next level and containing a set of primary packages. And the third level, the tertiary packaging, in turn contains several secondary packages and is often a pallet (Pålsson, 2018). The meal kit boxes of HelloFresh consist of a rather complex packaging system and it cannot be generalized, what is the primary and secondary packaging. Depending on the distribution country the packaging system can be slightly different. Therefore, in this report is just the system for the DACH countries (Germany, Austria and Switzerland) and the UK presented. According to Pålsson (2018) should a packaging system fulfil the following functions.

1. Protection
2. Containment
3. Apportionment
4. Unitization
5. Communication
6. Convenience

A meal-kit box is containing the ingredients of a whole meal, which need to be protected extraordinary. Due to the distribution via 3PLs the boxes are handled more roughly than a store-bought meal and the cold chain needs to be secured. Thus, a special focus lays on the protection of the product. Apportionment and unitization are especially important for the production efficiency and the supply chain logistics. Through the right choice of portions and modularization of the packaging system can food waste be reduced, and the distribution of the boxes be facilitated. The communication is crucial for the track and trace data as well as communication to towards the consumer with the branding, design and labelling. Although the convenience fulfils functions for different stakeholders throughout the supply chain and facilitates the easy handling in the production as well as for the consumer.

2.1.1 Meal Kit Box

The German meal kit boxes consist of a cardboard box, mainly the tertiary packaging, containing a cooling pouch and two or more so called kits (see Figure 2-1). The main functions of the cardboard box are the containment, apportionment and unitization. The kits are paper bags containing the ingredients for each meal, which do not need to be cooled. Depending, whether the containing food product is already packaged it is a primary or secondary packaging. E.g. in the case of rice, it would be the secondary packaging as the rice is packed in a bag, while for an onion, which comes only in a transport packaging to HelloFresh, it would be the primary packaging. Every kit is closed with a sticker in the same colour and number as the recipe card. This way the customer easily knows which bag to take for which meal. Therefore, their main functions are as well containment, apportionment, unitization plus communication for the consumer.

Figure 2-1: Meal-kit box.

The cooling pouch, a secondary packaging, contains the perishable food like meat and dairy products that need to be kept at a cool temperature. Thus, its main function is the protection of the product. There are different types of cooling pouch (see Figure 2-2): (a) paper-based, (b) PET (UK) and (c) PE (city pouch).

Figure 2-2: Cooling pouches, (a) paper-based (UK), (b) PET and (b) PE (city pouch).

The PET pouch, which is made of recycled material, is used in the UK. For the DACH countries and Sweden the pouch was recently switched to a paper-based material. Depending on the 3PL partner a non-insulated PE pouch is used as the distribution is done by cooling trucks.

2.1.2 **Paper Pouch**

The paper-based pouch consists of several layers of recycled cellulose glued together with an outer layer made of LDPE, so called spunbond (see Figure 2-3), that is sewed together. The pouch is bought from an external supplier. The recycled paper layers are produced in Austria with recycled paper from Austria and the surrounding countries. The layers of cellulose are bonded with a continuous loop of spunbond. The continuous loop of pouch material is then transported on trucks to the Czech Republic, where it gets cut and sewed to the final pouches. Usually the finished product is transported directly to the HelloFresh production in Verden, Germany (personal communication, April 2020). The pouches get ordered about 6-8 weeks before the meal kit production and is delivered weekly. The aim is to replace the city pouch and the PET pouch in the UK with a paper-based pouch as well (Aulich, 2020). There exist three different thicknesses for the paper pouches, depending on the layers of cellulose, classified in normal, light and super light. The choice of thickness depends on the outer temperature and the distribution way. The pouches are produced in three different sizes.

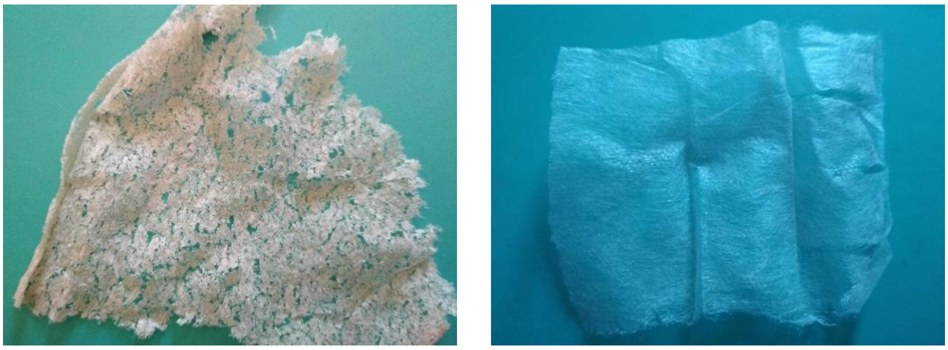

Figure 2-3: (a) Recycled cellulose material and (b) spunbond LDPE material.

2.2 Stakeholders

In the production and distribution of meal kit boxes are several different stakeholders included. In this report the focus is on the stakeholders directly involved in the handling of the cooling pouches. The first stakeholder in the supply chain is the supplier of the pouches. Next comes the pick-and-pack (PnP) staff, who pack the ingredients to the pouches and put them in the boxes. The 3PL plays no role in the handling of the cooling pouches as they are handling the boxes but do not have any contact with the pouches itself. At the use phase, the third stakeholder is the consumer, who unpacks the cooled products and discards the pouches. Additionally, the management of the company is considered as a stakeholder as the finances connected to the pouches are considered in this report. The requirements and demands of the stakeholders given in the next chapters are based on a packaging performance scorecard conducted in a previous project by Guardiola Ramírez (2019a).

2.2.1 **Supplier**

The supplier of the raw material, in this case the cooling pouch, is the first stakeholder in the supply chain. The paper pouches are supplied by a company from Germany, which specialises on the production of cellulose, cotton and non-woven fabric products. This stakeholder is responsible for the production, the quality and the distribution of the raw material. The choice of the supplier has a direct influence on the costs and the environmental impact of the packaging material.

2.2.2 **PnP Staff**

The next stakeholder in the SC is the production of HelloFresh, more precisely the PnP staff handling the paper pouch in the packing process of the meal kit box. The most important properties for the cooling pouch are the material handling and apportionment. The pouch should e.g. be flexible, make no sound and easy to close. Also, the hazards play a role and the risk of paper cuts should be kept to a minimum. This feature can also be secured through personal safety equipment like gloves and has therefore a minor role (Guardiola Ramírez, 2019a, p. 42-43).

2.2.3 **Consumer**

The consumer is the last stakeholder handling the CP before its end of its life. The first point of contact is at the unpacking of the ingredients. All chilled products are contained in the pouch. The consumer opens the pouch, puts the chilled ingredients in the fridge and discards the CP in the waste bin. Most important for the consumer are the packaging waste and convenience features. The consumer wishes for a sustainable packaging choice, which is easy to dispose of. It should also not be bulky. Another important factor is the easiness of opening and closing the pouch (Guardiola Ramírez, 2019a, p. 45-46).

2.2.4 **Management**

The management of HelloFresh has no direct contact with the paper pouch in its stages of life. Nevertheless, it needs to be considered as it makes the decisions. For the management of HelloFresh, the apportionment plays an important role, as the aim is to have the best filled box (product/air ratio). Another important feature is the production efficiency and packaging waste to keep the costs for the packaging low. The main factor for the packaging waste is the licencing fee, which is lower for paper than plastic and is calculated per amount of produced packaging (Guardiola Ramírez, 2019a, p. 43-44).

2.3 Packing Process

To get a better understanding of the requirements and challenges for the paper pouches it is important to know the production process of the meal kit boxes. The process starts with the receiving of the raw material. Depending on the type of the raw material it is either stored in the ambient storage, the chilled or frozen area. The paper pouches are delivered weekly and are ordered 6-8 weeks before production.

Before the production starts are the raw materials needed for the day moved to an area in front of the production line that is called ‘supermarket’. The packaging material – carton boxes, cooling pouches and paper bags – is stored at the production line.

At the production site in the UK exist two different production lines. The older ‘Legacy Line’, which is like the production line in Germany and Sweden, and the newer ‘Single Line’. The boxes produced at the older line contain paper bags with the non-cooled ingredients for each meal. These kit bags are pre-produced at the ‘kitting area’ and are stored temporarily in dollies, which are transported to the assembly line. There is a process quite like the single line.

For nearly all packing processes, a pick to light system is applied. Every station in the line is equipped with a hand-scanner. When the worker scans the barcode on the label of the box, one or several buttons with a light turn on, indicating which product to pick. Next to the light appears a number showing how many pieces of the product need to be added to the box. After adding the product, the worker pushes the button and the box can be forwarded to the next station. If one product/button was missed, the next station gets an error sign after scanning the box and it needs to be pushed back to the previous station and be controlled. The packing is done in an unsorted system. This means that different box types (e.g. different number of meals, persons and recipes) are done in one packing process. The packing process at the kitting line is done in a sorted process as there is no pick to light system implemented. This means that one kit bag for one recipe is done in one area. There are several kitting lines to produce different kit bags at the same time. The bags are always filled with the same products.

The packing process at the assembly line starts with the attachment of the postage label and the erection of the boxes. These are put on a conveyor belt and pushed to the next station in the line. There a worker scans the barcode on the label and adds the cooling pouch according to the light. Afterwards the cooling pouch is filled with ice packs and the ingredients that need a constant cooling. Then is the cooling pouch closed with a label and the kit bags and the recipe cards are added. Afterwards the box is automatically closed and is placed on a pallet according to the direction where it is delivered to.

2.4 Thermal Properties

The most important feature of the cooling pouch is the thermal insulation function to ensure an uninterrupted cold chain. To assess, if an insulation material shows the needed properties it is necessary to understand the parameters influencing the insulation and how it is measured. Figure 2-4 shows the features affecting the insulation performance of a cooling pouch identified by Guardiola Ramírez (2019b), which are the thermal conductivity, compressibility, thickness and homogeneity of the insulation material.

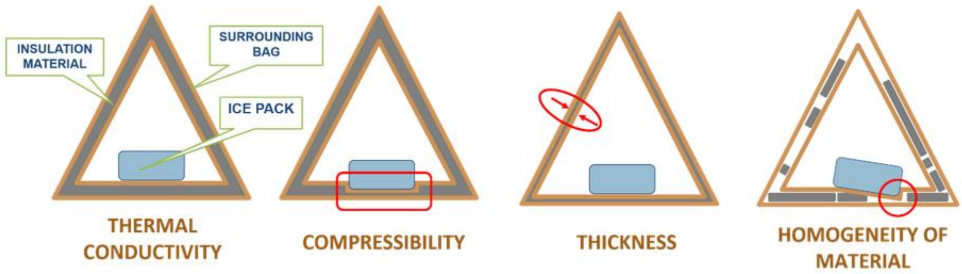

Figure 2-4: Scheme for features affecting the thermal insulation performance of a cooling pouch (Guardiola Ramírez, 2019b).

The thermal conductivity of a material indicates the rate of heat transfer and is described as the ‘amount of heat that will be conducted per unit time through a unit thickness of the material if a unit temperature gradient exists across that thickness. Conductive heat transfer characterizes the heat transfer through solid materials on a molecular basis. The conduction of heat is taking place from regions with higher temperature to regions with lower temperature either through the vibrations of molecules or the drift of electrons. The conductive heat transfer is denoted in Watt (W) per meter (m) Kelvin (K) ($Wm^{-1}K^{-1}$) (Singh & Heldman, 2009, p. 278, 282-284). Figure 2-5 depicts the heat transfer mechanisms in the cooling pouch. Heat is not only transferred via conduction but also via convection through the trapped air in the cooling pouch. As all different pouch solutions will have some air trapped inside it is assumed that the convective heat transfer is approximately the same for all solutions and that it is enough to compare the conductive heat transfer of different materials.

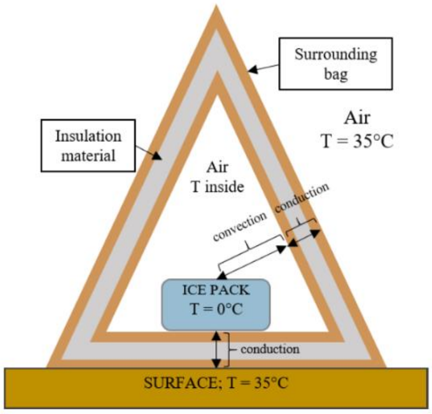

Figure 2-5: Heat transfer mechanism in the cooling pouch (Guardiola Ramírez, 2019a, p. 34).

2.5 Waste Management

At the end of a product life the packaging is generating waste. According to the European Council (2008) is waste defined as 'any substance or object which the holder discards or intends or is required to discard'. HelloFresh is aiming for a fully recyclable packaging solution for the meal kit boxes. To understand what fully recyclable means it is important to know the legislation for waste management and the recycling processes. This is done in the report exemplary for Germany and the UK.

2.5.1 **Legislation**

In the European Union is the waste management regulated by the Waste Framework Directive (WFD), which was adopted in 2008. It describes the underlying concepts and definitions for waste management and specifies waste management principles. Among these principles are the 'waste hierarchy' and the 'extended producer responsibility'. The waste hierarchy gives the priority in the legislation for waste prevention and management (see Figure 2-6). Every Member State is advised to take measures for the best environmental outcome. The extended producer responsibility was implemented to strengthen the waste hierarchy and reduce disposal. That means that the management of the waste and the financial responsibility lays in the hand of the producer (European Council, 2008).

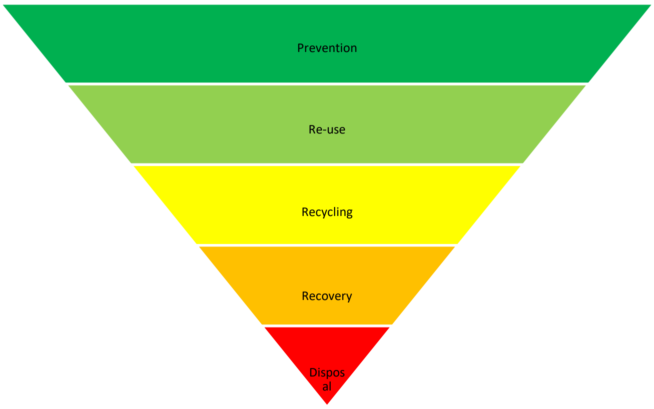

Figure 2-6: Waste hierarchy.

Another European Law applying to the waste management of the meal kit industry is the Packaging and Packaging Waste Directive (European Council, 1994). The directive harmonizes the national measures to minimise the environmental impact and gives targets for the shares of packaging materials.

German waste management is regulated by the federal Circular Economy Act (KrWG) introduced in 2012, which brings the WFD into national laws. This act is accompanied by the Packaging Act, which gives further details for the recycling of packaging. In 2017, a national authority was founded, called 'Zentrale Stelle'. This authority is financed by systems and operators of industry solutions respective to their market share. Manufacturers must register a new packaging at the authority before putting it on the market (Landbell AG, 2019). The collection and recycling of the waste is organised by a dual system. The producer pays a licence according to the amount and type of the packaging they are producing. The dual system organises the collection of the waste. The most known partner of the dual system is 'Grüner Punkt', which was the only partner until 2003 (Die dualen Systeme, 2020) and was chosen by HelloFresh as well. The consumer is already separating the waste at home in paper, glass, organic waste, residual waste and the so-called 'yellow bin'. The yellow bin is not just for plastic waste but also aluminium, tin plates and composite materials, e.g. TetraPak (Der Grüne Punkt, 2020).

In the UK is the WFD incorporated in 'The Waste (England and Wales) Regulations 2011' and the waste management of packaging material is guided by the 'Packaging (Essential Requirements) Regulations 2015' and the 'The Producer Responsibility Obligations (Packaging Waste) (Miscellaneous Amendments) Regulations 2016'. The Regulations set the essential requirements for the packaging material, e.g. that the volume and weight of the packaging should be at a minimum (UK Government, 2015). To fulfil the producer responsibilities a company, that is producing packaged goods, must register as a packaging producer and join a compliance scheme (in this case Wastepack). The company must provide packaging data to the National Packaging Waste Database (NPWD) and review the recovery and recycling obligation (UK Government 2018). There is no central system in the UK for the waste separation and collection, but it is organised differently for each council. Therefore, it might be that one consumer could separate the waste into many different and another in just two bins, recyclable or not recyclable. To facilitate the waste separation for the consumer an organisation called OPRL (on-pack recycling label) exists. The OPRL is a label that indicates if a packaging is recyclable or not (OPRL, 2020).

2.5.2 Paper Recycling

The production of recycled paper is quite like the production of virgin fibres, but some previous steps are needed (see Figure 2-7). First, the paper needs to be collected. As the previous chapter showed the collection system can be different on a national and regional level. The paper needs to be collected and kept separated from other waste to avoid contamination of the paper. At the recycling plant the paper is sorted into different grades. In the next step is a pulp created and contaminants that are large and non-fibrous (e.g. plastics) are removed. As a last step before the production of a new paper product needs the pulp to be de-inked. Ink from e.g. newspapers and labels is removed via a flotation process, in which air is blown into the pulp. The ink adhered to bubbles rises to the surface. Additionally, the paper can be bleached with hydrogen peroxide, if a white paper is needed (European Paper Recycling Council, 2019).

Figure 2-7: Paper recycling process.

3 Methodology

This chapter explains the methodology used to answer the research questions. First are the data collection methods explained followed by the analyses conducted with the data including an environmental impact assessment, cost assessment and the comparison of all factors.

3.1 Data Collection

To find answers to the previously formulated research questions mainly data needs to be collected. Such a complex topic like the sustainability of a process requires a mixed data collection method of primary and secondary data (Megel & Heermann, 1994, p. 204). The collection of primary data was mainly informal and semi-structured interviews with different stakeholders in the SC and external experts in person and via email used. Also, the observational method was used for a deeper understanding of the production processes at the HelloFresh production and external companies. The informal talks were mainly in the beginning of the research used to get a better understanding of the meal kit industry, material properties and possibilities for processing alternatives.

3.1.1 **Primary Data Collection**

3.1.1.1 Data collected from machine producers & suppliers

As a first step of the primary data collection was the European market screened by a web and literature research and input from the HelloFresh supervisor for exemplary machine producers and material suppliers. The research was not restricted to just already implemented machines and materials, but also new ideas were developed. Following criteria were used for the search:

- European supplier (especially for material to keep distances short)
- Paper-based material
- Recyclable material
- Producers of machines for the cooling material, Jiffy bags or similar

- Available in the European market (+UK) and possibility to implement it in other markets as well

The screening was conducted to gain an overview of the possibilities and to facilitate innovative and creative ideas. As it was most likely no process/machine already existed, the main aim was to find companies suitable for the building of a custom-made process/machine.

After identifying appropriate companies, they were contacted by the researcher via phone or mail to gather relevant data for cost assessment and environmental impact assessment that could not be drawn from literature. The existing supplier was contacted as well to complete process relevant information about the costs and environmental burden. Table 1 shows a list of contacted people and gathered information.

Table 1: List of contacted external people for the case study research.

Company	***Position/Name***	***Obtained information***
Machine producers/material suppliers		
VFFS machine producer	Area Sales Manager	• Setting options for the VFFS machine • Difference of sealing systems • Possible dimensions of pouches • Testing process • Feasibility
Producer for upholstery cushions	CEO	• Setting options for the VFFS machine • Price • Energy consumption • Material options • Feasibility
Producer for insulated box liners	Business Development Leader	• Progress of developments • Material properties

Producer for insulation pouches	Quality Manager	• Production process of paper pouch • Transportation routes • Truck filling rates • Energy consumption of production process
Producer for paper film (a)	Market Manager Packaging Solution	• Paper film • Transportation modalities • Prices
Producer for paper film (b)	Sales Director Flexible Packaging	• Paper film • Transportation modalities • Prices
Paper mill	Senior Management	• Cellulose • Transportation modalities • Prices
Producer for cellulose fibres	Product Manager Industry International	• Technical raw cellulose • Transportation modalities • Prices
Other information		
Recycling company (a)	Material Flow Management	• Recyclability of paper pouch • Recycling process
Recycling company (b)	Recycling Division	• Recyclability of paper pouch • Recycling process in UK

3.1.1.2 Data collected from HelloFresh

To understand the current purchasing and packing process as well as the characteristics and specifications of the cooling pouches at HelloFresh several methods were used. First an observation in the production facility and the international laboratory in England was conducted to gain a deeper understanding of the packing process and testing of thermal properties. The main sets of data were gathered through email and personal contact with different members of the HelloFresh group, mainly procurement, packaging development and sustainability management. Table 2 shows the contacted people from HelloFresh and the gathered information.

Table 2: List of contacted people from HelloFresh for the case study research.

Company	*Position/Name*	*Obtained information*
HelloFresh Internal		
HelloFresh Global	Head of Packaging	• General packaging specific information • General packaging processes
HelloFresh DE	Procurement Specialist	• Purchase process • Pouch production • Usage of pouch types • Waste licencing system
HelloFresh Global	Senior Quality Manager	• Quality criteria • Testing of pouches • Pouch types
HelloFresh Global	International Laboratory Lead	• Testing possibilities in the International Test Laboratory of HelloFresh • Introduction to different tests • Evaluation of tests
HelloFresh Global	Sustainability Manager	• Carbon reporting • Carbon offsetting
HelloFresh Global	Operational Excellence Engineer	• General process information
HelloFresh Global	International Supply Chain Sustainability Manager	• Carbon reporting for transportation processes

3.1.2 **Secondary Data Collection**

3.1.2.1 Packaging specification

For the search of new processing possibilities and consequently potential new materials, it was important to specify the needed properties and functions of the insulation material. To understand the material specification for the material and needed properties a set of internal data from the International Test Laboratory at HelloFresh UK was viewed. These tests consisted of ice melt tests as well as climate chamber tests. This data was used to assess the thermal properties specifications accompanied by internal specification documents.

A cooling pouch must not only fulfil its function as an insulation material but also perform in an adequate manner for the involved stakeholders in a life cycle of the packaging. To assess relevant stakeholders and the performance of a packaging the packaging performance methodologies can be used, and a packaging scorecard created. This was done by Guardiola Ramírez (2019a), who provided relevant information for the relevant packaging features for each stakeholder.

3.1.2.2 Environmental impact data

An in-house production must not necessarily be more environmentally friendly than the purchase of packaging material. To assess the environmental impact of the alternative processes a simplified Life Cycle Assessment was conducted. Where no primary data were given, assumptions were taken, and literature-based numbers used.

3.2 Data Analysis

The collected data were used for a holistic analysis of the in-house production of insulation material for the meal kit industry, which was conducted in an iterative process with the data collection in the prototyping process. As a new and innovative process for the production was considered, a prototyping process had to be done. Qualitative data from interviews, informal talks and observations was used to form ideas for a possible pouch type and to find a start for the prototyping process. With the help of the qualitative data and the prototyping it was possible to evaluate the feasibility of the new concept and collect data for the following environmental and economical impact analysis. For these analyses were quantitative data, e.g. truck filling rates as well as the qualitative data, which were transformed to quantitative data (e.g. production places used for the calculation of tonne-kilometres) used. Finally, the analyses were compared in a ranking system to facilitate a justified recommendation.

3.2.1 **Prototyping**

"Designing for sustainability requires a commitment to rethink the design of the product-packaging system." (Verghese, Lewis, & Fitzpatrick, 2012)

To ensure the most sustainable options were considered in the project, not just the existing pouch concept was considered but also a new concept was created. The

Engineering Design Process is a useful tool to facilitate the creation of a new packaging solution (see Figure 3-1).

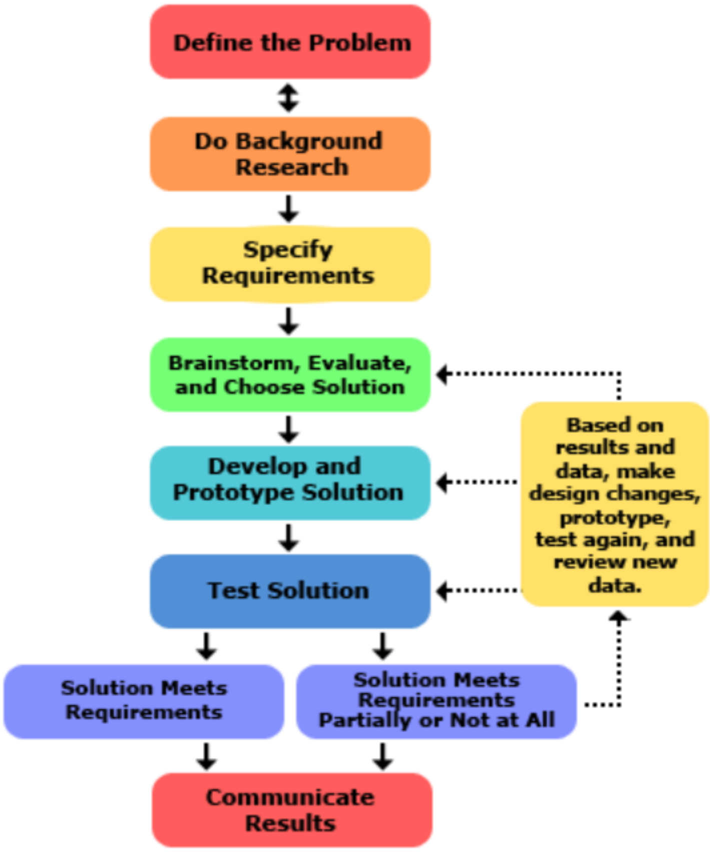

Figure 3-1: Engineering Design Process Scheme (Science Buddies, 2020).

The first four steps of the process were done rather unstructured. The idea for the new packaging design existed already roughly before the start of the project. The idea was further developed through the internet-based research for materials and telephone conferences with the partner. Table 1 shows the list of test material that was used for the prototyping.

Table 3: List of test material.

Material	***Properties***
Paper film	One side single coated MF paper with sealable coating on the reverse side
Paper film	Heat-sealable paper made of virgin fibre pulp with a mineral oil barrier
Insulation material	Functional filler of technical raw cellulose
Insulation material & paper shred filled pouches	Recycled paper and carton shredded to small pieces (filled in a paper bag)
Cellulose/paper	Highly absorbent paper
Spunbond	

The next step was the prototyping, which was conducted through the researcher as well as an external company. Prototyping can fulfil several functions such as (a) developing ideas, (b) experience user perspective and expectations, (c) communication and (d) validation and testing. The prototypes can be divided into *design prototypes* and *technological prototypes*, while the design prototype is created in the early stage of a project. It is used for the ideation and problem identification of a concept. Later it transforms into a technological prototype when it is used for the testing and proofing of a determined function (Gengnagel, Nagy & Stark, 2016, p. 5). Prototyping is an iterative process and the transition is smooth.

3.2.2 Assessing Production Feasibility

Before an environmental and economical impact assessment could be conducted, the production modalities had to be assessed to gain data about the feasibility of the production alternatives and the consumption rates of the different resources. Collected qualitative data were reviewed on a subjective basis. The feasibility of the production alternatives depends on different factors. First, the supply of the raw material needs to be considered. E.g. it needed to be determined what the possible formats are. For this purpose, the suppliers were contacted and interviewed. Internal possibilities at HelloFresh were checked as well. This information and the insights of the prototyping process were used to calculate consumption rates and required machinery.

Another factor to be considered is the handling of the raw material and finished products. Once again suppliers and machine producers were contacted and interviewed. Additionally, the production facility of HelloFresh in Germany was visited to brainstorm possibilities and give recommendations.

3.2.3 **Environmental Impact Analysis**

To analyse the environmental impact of a process a Life Cycle Assessment (LCA) is a useful tool. It helps to determine the impact of a product from the raw material acquisition, throughout the production process until its end of life (Finnveden et al., 2009). In this project an environmental impact analysis has been done based on the principles of an LCA in a simplified method as a complete LCA is a too complex and time-consuming analysis. A Life Cycle Assessment consists of four steps (see Figure 3-2): (1) goal and scope definition, (2) inventory analysis, (3) impact assessment and (4) interpretation.

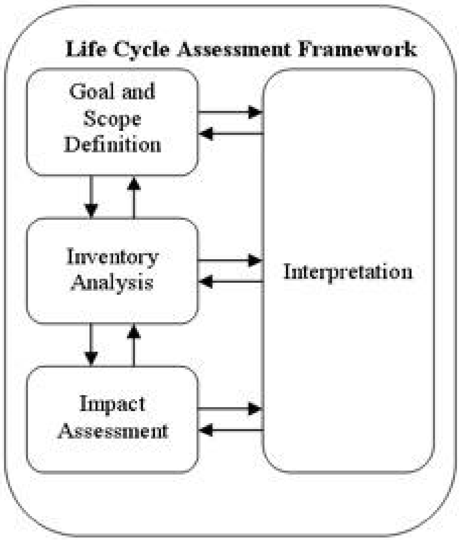

Figure 3-2: Life Cycle Assessment Framework (https://www.lifecycleinitiative.org/starting-life-cycle-thinking/life-cycle-approaches/environmental-lca/).

A Life Cycle Assessment can be done either from cradle to grave or from gate to gate. Which means that either the whole product life from the cultivation of the raw material to the disposal of the product is reviewed or just a certain process is in the product life.

3.2.3.1 Goal & scope definition

The first step in an LCA is to describe the product system and define a functional unit, which is needed to be able to assess the process and compare it with an alternative. It can be a model of one or more product systems that fulfil a function. That function is evaluated by the means of a functional unit. This way the different required resources, emissions and generated waste per functional unit can be assessed. The functional unit is described as the quantitative characterization of the fulfilled needs of the investigated product system (Rebitzer et. al., 2004). This can be e.g. one kilogram of finished product. In this case study, the functional unit was set as a finished pouch. This is a suitable functional unit as different production and purchasing processes of the insulation material were compared that have the output of a cooling pouch consequently. It should be kept in mind that the insulation properties of the cooling pouches could not be tested, and the calculations were done assuming the same insulation properties for all different pouch types.

3.2.3.2 Inventory analysis

For the Inventory Analysis (IA) of an LCA is data for each considered process required which consists of inputs and outputs connected to the product or function generated by the process (LIFE Programme, 2004). The collected data (see 3.1 for methods) is validated and linked to the functional unit. In case of a multifunction process, e.g. a process with more than one product, an important step in the IA the allocation of flows. There might be the problem that two or more products share an environmental burden and it needs to be decided what ratio needs to be included. An open-loop recycling counts to a multifunction process as well as the recycled material fulfils a function for life cycles of other products (Ekvall & Finnveden, 2001).

3.2.3.3 Impact assessment

The Life Cycle Impact Assessment (LCIA) translates the collected data to the environmental impact by providing indicators and the basis for the analysis of the potential contributions of the resources. The product's life cycle is evaluated based on the functional unit regarding different impact categories like land use, climate change and toxicological stress (Rebitzer et.al., 2004).

As previously mentioned, a complete LCA would have been too time-consuming and too much information was missing. Therefore, it was decided to only analyse the carbon impact of the most important parts of the process. In 2010 25% of the global greenhouse gas emissions originated from electricity and heat production, 21% from the energy and 14% from the transport sector (Edenhofer et.al., 2014). This shows that the energy consumption by the production and the freight transport play a major role in the greenhouse gas emissions. The focus should be set on the comparison of the emission through used energy for the production and the transport of the raw material and goods. To allow other greenhouse gases (GHG) to be included, if they have a significant impact on the emissions, CO_2-equivalents were chosen as the impact category. With CO_2-equivalents other greenhouse gas (GHG) emissions can be converted to the climate impact of CO_2 emissions and be expressed in that way on the same calculation (UK Government, n.d.). The Greenhouse Gas

Protocol established by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) differentiates between three different scopes of emissions accounting.

1. Scope: Direct emissions
2. Scope: Electricity emissions
3. Scope: Supply chain emissions

While the direct emissions are owned or controlled by the company, the emissions resulting from electricity consumption are indirect emissions and the supply chain emissions are resulting from transportation of goods. For the carbon impact analysis of this report only scope 2 and 3 emissions were calculated. As there are no scope 1 emissions directly linked to the production of insulation material and no data was given from the suppliers, were these emissions excluded from the analysis.

To calculate the scope 2 emissions, caused using electricity in the production process, the electricity emission factor (see Equation 1) is needed. The electricity emission factor is dependent on the country or region, where the product is manufactured and is influenced by the energy mix (Green & Lewis, 2019). Further can be distinguished between the local-based and market-based emission factor when reporting GHG emissions. Contrary to the local-based emission factor, the market-based factor does only account for the purchased energy. This means that if a company is having a contract with a provider for renewable energy, the market-based emission factor might be lower than the local-based emission factor (Boscolo, 2020). A decrease in the emissions is necessary to achieve the sustainable development goals. The choice of the emission factor depends on the scope of the report and what type of decision the numbers are used for. E.g. for production location decisions it might be useful to look on the local-based factors. The market-based factor on the other hand could be used for decisions to influence the grid mix in a location (Sotos, 2015, p. 25-31). To demonstrate the difference between the reporting methods two scenarios were calculated. The first scenario is based on the local emission factor while the second scenario is taking market-based factors into account.

Equation 1: Electricity emission factor for the calculation of scope 2 emissions.

$$Electricity\ emission\ factor = \frac{kg\ CO_2e}{kWh\ electricity}$$

There exist many different sources for the local-based emission factors. For the calculation in this report the emission factors from the *Covenant of Mayors* (n.d.) were taken. For the market-based emissions in most cases no exact data about the emissions or the source of the renewable energy were given, only information about the percentage of renewable energy. In that case, the average emission factor of solar energy, wind power and hydro power was taken from the *Covenant of Mayors* (n.d.).

Based on the consumed energy in the production process and the machine output per hour can the GHG emissions per pouch be calculated (see Equation 2). Only for the calculation of the current pouch was the energy consumption per kilogram of raw material already given. In the case of missing data about energy consumption or machine outputs were the numbers of similar processes assumed.

Equation 2: GHG emissions of scope 2 assets.

$$kg\ CO_2e\ emissions = \frac{electricity\ emission\ factor * energy\ consumption}{machine\ output}$$

Scope 3 emissions would be most accurately calculated by determining the amount of used fuel per transport process. Unfortunately, the amount of used fuel often cannot be determined. In this case the weight of the good and the shipped distance should be accounted for by multiplication, resulting in tonne-kilometres in Equation 3 (Green & Lewis, 2019).

Equation 3: Calculation of tonne-kilometres.

$$tonne - km = tonnes\ x\ kilometres$$

For the calculation, the actual distance or planned distance should be taken as it takes operating conditions such as restrictions of the vehicle or road type into account (Green & Lewis, 2019). Due to missing information about actual planned routes, the shortest feasible distance was determined via Google Maps instead. When the starting point of the route was unknown or the raw material was sourced from different locations, 500 km was taken as the average distance. This resembles half of the average furthest distance in the DACH region. In the next steps, the activity data needs to be converted to emissions, which can be done via a fuel efficiency factor (see Equation 4) or a CO_2e intensity factor (Equation 5).

Equation 4: Calculation of CO_2e emissions of a truck via the fuel emission factor.

$$kg\ CO_2e\ emissions/truck = \sum_{1}^{n}\left(total\ tkm\ x\ fuel\ efficiency\ factor\ \left(\frac{kg\ fuel}{tonne - km}\right)\ x\ fuel\ emission\ factor\ \left(\frac{kg\ CO_2e}{kg\ fuel}\right)\right)$$

Equation 5: Calculation of CO_2e emissions of a truck via the CO_2e intensity factor.

$$kg\ CO_2e\ emissions/truck = \sum_{1}^{n}\left(total\ tkm\ x\ \ CO_2e\ intensity\ factor\ \left(\frac{kg\ CO_2e}{tonne - km}\right)\right)$$

Generally, many different countries and organisations provide a detailed database for the emission factors. As HelloFresh does its emissions reporting with the GLEC (Global Logistics Emissions Council) framework this database was chosen for the calculations in the report. It provides detailed data for the European freight transport. To account for the full impact of fuel use Well-to-Wheel (WTW) emissions were considered in the calculations. This means that the full life cycle of the fuel from production and distributions (Well-to-Tank, WTT) to the combustion (Tank-to-Wheel, TTW) was considered (Green & Lewis, 2019). Based on the information given by the supplier the emission factor was chosen, e.g. an artic truck up to 40 tonnes with average laden using diesel as fuel. For this type of lorry accounts the WTW emission factor with 92 kg CO_2e/t-km (Green & Lewis, 2019). When no other information was given this type was assumed for the calculations of the other production and supplier alternatives as well. The transport processes were divided in the transport of the raw material (a), semi-finished product (b) and the finished product (c). For the transportation of the actual pouch did the supplier provide the amounts of pouches per carton, cartons per pallet and pallets per truck as well as the weight of the different pouch sizes. The weight of a EURO pallet (European Pallet Association e.V., 2020) was included as well as an addition of 10% for the secondary packaging. The amounts of transported pouches were then calculated, and the emissions per pouch were calculated with Equation 6. The numbers of this calculation step are not shown in this report due to the sensitivity of the information.

Equation 6: Calculation of CO_2e emissions of a pouch caused by transportation.

$$kg\ CO_2e\ emissions/pouch = \frac{kg\ CO_2e\ emissions/truck}{pouches/truck}$$

The system boundaries were set from the production of the supplier to the production of HelloFresh, which accounts for the inbound logistics of HelloFresh and major production processes. It was not enough data given for the calculation of the emissions produced by the transport of the raw material to the supplier, the waste cardboard and spunbond. To reduce the complexity and create a comparable basis were the most processes calculated for the normal pouch as it is the most used pouch type.

3.2.4 **Cost Assessment**

To review the pouch production process in terms of the second pillar of sustainability, the economical sustainability, a cost assessment was conducted. To analyse different production processes and machines for their economical benefits is a common situation in a business. Thus, offers HelloFresh a standard procedure how to compare these processes and facilitate a justified decision based on the cost assessment. The provided business case template was used for the cost assessment of the processing alternatives for this project.

The collected data concerning the cost contribution of the packaging material to the product were analysed in a cost contribution calculation. Since the cooling pouch is just a part of the final product (the meal kit box) the cost analysis was done per pouch. To be able to calculate the prices per pouch a forecasted volume and the machine output needs to be assessed. The machine output depends on the theoretical possible output and the machine efficiency. The machine efficiency depends on the availability of the machine, the performance and the quality of the products that reduce the output of the machine (Zepf, 2013). When calculating the costs connected to the production with a new machine, it should not be assumed that the efficiency is at 100%. It would be better to be around 85%, which is the standard factor used at HelloFresh. The machine efficiency is used to calculate the machine capacity, which depends on the output of the machine, the efficiency and the running hours per week (see Equation 7). The running hours per week depends on the production modes and the available personnel. In the case of HelloFresh, a production in two shifts of five days would be possible.

Equation 7: Calculation of machine capacity.

$$\frac{Machine\ capacity}{week} = \frac{Output}{min} * Machine\ efficiency * \frac{Running\ hours}{week}$$

When one machine is not enough to produce the demand of pouches, the number of machines needs to be increased. The necessary number of machines were calculated with Equation 8. Due to the sensitivity of the data the numbers are not shown in this report.

Equation 8: Calculation of the machines needed to meet the demand.

$$Machines\ needed = \frac{Demand\ pouches/week}{\frac{Machine\ capacity}{week}}$$

The next step in a business case calculation is the assessment of the fixed costs and variable costs. Fixed costs are independent from company activities and occur on a regular basis, e.g. rent and depreciation. Additional variable costs, which depend on the production volume, e.g. raw material and leased personnel. Together these costs add up to the total cost of a produced product (see Figure 3-3). (PrepLounge, 2020)

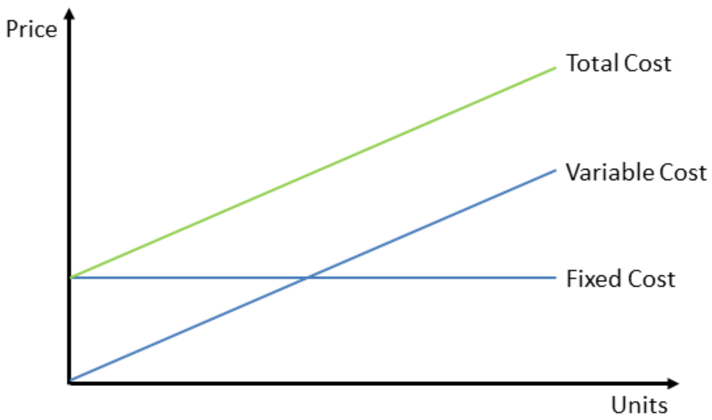

Figure 3-3: Diagram showing fixed costs vs. variable costs (PrepLounge, 2020).

With the purchase of a new machine occurs a set of investment costs. First, for the equipment itself but also for the transport, installation, automation and set up. These costs are summarised to investment costs. The investment costs are then allocated via the depreciation over its life expectancy. This way, the investment can be expensed partly for each year and is considered via the fixed costs (Tuovila, 2020). The life expectancy is often set between 5 and 10 years. In this case study, five years were chosen. Table 4 shows the different factors considered in the cost assessment.

Table 4: List of fixed and variable costs considered in the cost assessment.

Fixed costs	***Variable costs***
Depreciation: • Equipment • Transport • Installation • Internal Transport & Equipment • Unforeseen	Raw material: • Paper film • Insulation filling material • Spunbond • Cellulose
	Energy
	Labour

Due to the variable costs, the cost of one pouch depends on the production volume. For this reason, it is useful to do a break-even analysis. This analysis shows at which sales point the revenue is equal to the production cost (see Figure 3-4). In other words, at which point the production method would be profitable (Anguelov & Tamošiūnienė, 2011). As the product is not directly sold further but a part of another product does the break-even point need to be calculated differently. In this case is the break-even point reached, when the variable costs exceed the total fixed costs. Equation 9 shows the calculation of the break-even point.

Equation 9: Calculation of break-even point.

$$Break-even\ point\ (weeks) = \frac{Total\ fixed\ costs}{Variable\ costs * weekly\ production\ volume}$$

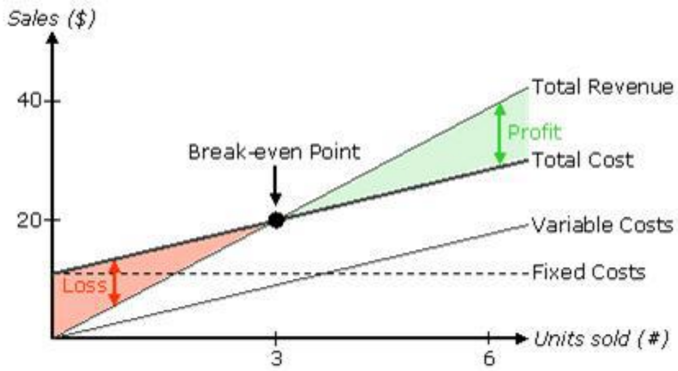

Figure 3-4: Break-even analysis (Anguelov & Tamošiūnienė, 2011).

HelloFresh has chosen to offset the carbon emissions that cannot be avoided in the production process. Carbon offsetting means that a company compensates the produced CO_2 emissions via financing a project that deprives greenhouse gases from the atmosphere, like projects for planting trees, or that prevent the emissions of GHG through other factors (Merriam-Webster, 2020). There exist numerous projects for carbon offsetting, but the principle is similar. The company pays a price per tonne of CO_2e emitted, which then is used to finance a project for the reduction of the greenhouse gas emissions. Carbon offsetting is a controversial topic and should be reviewed critically. The IPCC (Rogelj et.al., 2018) states that the carbon emissions need to be reduced drastically to neutral to prevent a temperature rise more than 1.5°C. Thus, the carbon emissions should be reduced and not compensated as this cannot only be achieved with carbon offsetting only. Unfortunately, the price for carbon offsetting is quite low. HelloFresh is paying around six Euro per tonne on average. This could provide an incentive to offset carbon instead of reducing it. Nevertheless, HelloFresh is already compensating for the carbon emissions and is still continuously searching for solutions to reduce the emissions. Thus, calculating the saved offsets could give a production alternative an extra appeal. By subtracting the saved costs from the possible additional costs through the new production alternative it can be seen, if this process might still be more economically sustainable for the company. On the other hand, if the alternative production process is already more cost effective, the saved carbon offsetting could be an extra on top. Thus, the costs for carbon offsetting were considered additionally.

3.2.4.1 Delimitations and Assumptions

All production alternatives are based on custom-made machines and materials. Thus, it is not offered on the market regularly and no exact data was available. In this case, assumptions and rough estimations had to be done by the researcher and suppliers. Table 5 gives an overview on the assumptions taken in this project.

Table 5: Assumptions and estimations for the cost impact assessment.

Category	*Alternative*	*Description*	*Based on*	*Done by*
Machine output	1	Feasible machine capacity	Old pouch production	Researcher
Investment cost	1	Equipment cost/machine	Other business cases	Researcher
Investment cost	1 & 2	Automation, Internal Transport, HF Infrastructure etc.	Other business cases	Researcher
Variable costs	1 & 2	Raw material prices	-	Supplier
Variable costs	1	Employees/machine	Status quo process	Researcher
Variable costs	1	Energy consumption sewing machine	Comparable machine available on market	Researcher
Variable costs	1	Service & Maintenance	Other business cases	Researcher

3.2.5 Comparison of All Factors

Generally, everything should be done for sustainable production and there should be no question of costs, if a more environmentally friendly process is chosen. Nevertheless, the economical sustainability also plays an important role in a company and the feasibility of a production process needs to be considered. Thus, a metric is needed to compare the economical and the environmental impact of a production alternative. It was chosen to create a ranking system. Each assessment – feasibility, carbon impact and cost impact – provides a ranking from one to four for the four production alternatives. One is the worst performing alternative and four the best performing alternative. E.g. if an alternative shows the lowest carbon impact, it gets the highest points of four. In the same way, it was preceded with the cost impact assessment. Both analyses show quantitative numbers which can be easily translated to the ranking. The feasibility analysis is a qualitative analysis and was rated by the researcher. Into consideration were taken the following aspects:

- (Non) existing pouch concept
- Know-how needed
- (Tested) insulation properties
- Needed space, infrastructure etc.

Subsequently, the points of the three rankings were added up and compared for each alternative. The alternative with the highest number of points is the most favourable alternative.

4 Results & Discussion

The chapter presents the results from the case study. First are the identified production alternatives and the prototyping process described. Consecutively is the gathered data from the production alternatives and prototypes assessed for their environmental and economical impact. In conclusion are the results from the analyses compared and reviewed.

4.1 Production Alternatives

The screening of the European market and the web and literature research showed that there are three possible production alternatives to the status quo process for the insulation material. The first alternative is to stay at in the existing insulation pouch format. The raw material for the pouch would be sourced from external suppliers but the forming would be done at the production site of HelloFresh. This solution was chosen to be one alternative as the material is already successfully used and the implementation seemed relatively uncomplicated.

The other two alternatives would result in another material and format of the cooling pouch. Alternative 2 can be considered as the innovative process. There would be a Vertical Form Fill Seal (VFFS) machine used to produce a band of several paper pouches filled with a paper-based insulation material. This band of pouches would be in a next processing step be folded and closed to a pouch in the format of the actual one (see Figure 4-1). The compartments of the pouch should have the same width as the actual pouches and a height of about 150-200mm was chosen as appropriate. Two possible machine manufacturers were identified for the realisation of this process. First, the company (a) is producing VFFS machines for the food industry, which HelloFresh had contact with prior to the thesis project. Second, the company (b), that offers a solution incorporating the paper waste from the production with an upstream shredder for the filling material in a cardboard recycling plant. These machines are usually used to produce cushions for the shipping of goods.

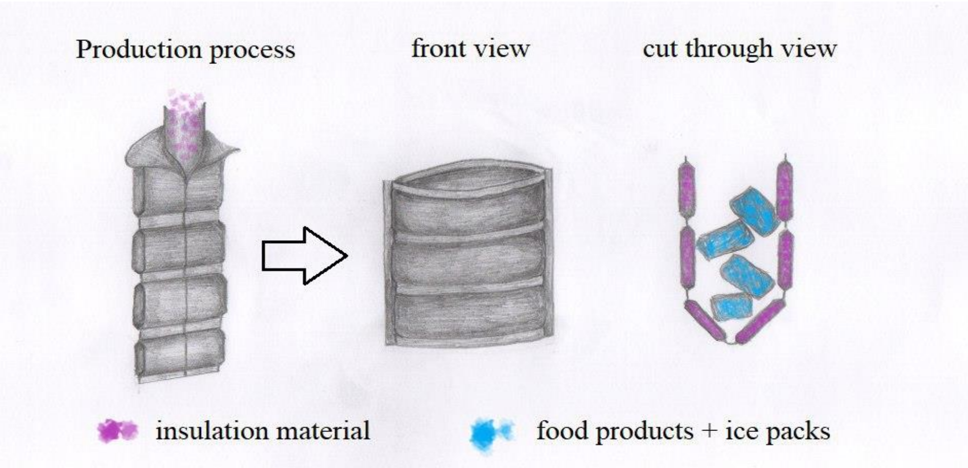

Figure 4-1: Concept layout for alternative 2.

The third alternative is an already existing concept on the market. It is a kraft paper liner with a padding made of cellulose fibres. This option was chosen to investigate further as HelloFresh was already in contact with a company producing these liners. Unfortunately, this option was ruled out right in the beginning, because a cooperation for an in-house production was not possible.

Table 6 shows an overview of the different production alternatives, the used materials and their level of implementation.

Table 6: Overview of production alternatives.

	Alternative 1	***Alternative 2***		***Alternative 3***
		(a)	*(b)*	
Description	Pouch like the status quo	2 step process: VFFS machine for a paper pouch chain filled with insulation material further formed to a pouch		Kraft liner with inner padding
Material	Cellulose + spunbond film	Paper film + purchased technical raw cellulose	Paper film + paper shred from own production	Kraft paper film + paper fibres
Existing insulation concept	x Used at HelloFresh			x
Extensive testing needed		x	x	x

While sourcing other processing alternatives another supplier for the existing pouch concept was discovered. The production of this supplier is based close to the production of HelloFresh. Therefore, it was considered as a fourth alternative although it would not be an in-house production. This alternative will show the impacts of transport processes regarding the environmental impact.

4.2 Prototyping

The second production alternative is a not yet existing insulation pouch concept. Before being able to calculate the environmental and economical impact of this solution, it was necessary to determine, if it would be possible to produce a pouch with sufficient insulation properties and functionalities. The type and amounts of material per pouch also needed to be determined for the following analysis. Therefore, the engineering design process was applied, and prototypes were built. The first design prototype was built by the researcher for the ideation of the concept and to gain insights in the challenges that might occur. For the building, paper bags were filled with specific paper shreds that were already available and are normally used for the cushioning of heavy shipped items. The aim was to build a pouch with the bags that can be filled with goods and create an example for the contacted suppliers to facilitate the explanation of the concept. The first try was done by sewing the pouches together with a standard needle and thread. Due to the bulging filling it was not possible to sew them together in a neat manner. Thus, the researcher switched to double-sided tape (see Figure 4-2).

Figure 4-2: First prototype.

Table 7 shows the conclusions that were drawn from the first prototype.

Table 7: Conclusions drawn from prototype 1.

Category	*Observation*	*Explanation*
Filling	Bags should be filled with less material	• Prototype is taking too much volume • Product did barely fit in the pouch • Pouch was quite inflexible • Challenge for the closing step
Process	Every last bag should be not filled	• Creating a closing flap like the current pouch
Process	3 possible pouch forming processes	• Sewing ○ Challenge: Paper film might not be strong enough • Glue/tape ○ Challenge: There might be no existing process • Sealing ○ Challenge: Filling material might inhibit sealing

To facilitate the prototyping a hand sealing machine was purchased. This way the existing paper bags could be opened and resealed again. To get an idea of how a pouch would look like two paper bags with paper shred were opened and emptied. Two prototypes (see Figure 4-4) were built, one with the paper shred and one with the pulp. The first prototype (2a) was filled with 20g of paper shred per compartment and the second one (2b) was filled with 15g of cellulose filling (see Figure 4-3).

Figure 4-3: Paper shred (left) and cellulose filling (right).

Both prototypes were sewn to a pouch with a simple needle and thread. Table 8 shows the properties that were created, and observations made.

Table 8: Properties and observations of prototype 2a and 2b.

	Prototype 2a	***Prototype 2b***
Filling	20g paper shred/compartment	15g cellulose filling/compartment
Compartments	4 + empty flap	6 (no flap)
Average height of compartment	95mm	80mm
Uniformity	Thinner and thicker parts in the filling	Uniform
Rigidity of pouch	Not as flexible as actual pouch	Little bit more flexible

For both prototypes was observed that the filling of the pouches is producing dust. This needs to be considered for the choice of the machine placement in the production.

Figure 4-4: Prototype 2a (right) and b (left).

A prototyping test at company (a) was planned for this project as the access to tools were limited for the researcher. The aim was to determine if a production with a VFFS machine would be possible. Unfortunately, this test was not conducted as the company stated that it will not be possible to fill the pouches with their knowledge and equipment, neither with a multihead weigher nor with a screw feeder. Especially the CIF is producing too much dust. Therefore, another test at company (b) was initiated. The company was instructed to build a pouch chain consisting of the longest possible width and shortest possible height. The company was able to produce the following different samples with the following average dimensions (see Table 9).

Table 9: Samples provided by company (b).

Compartments	Size			Weight	Volume	Density
	Width	*Length*	*Thickness*			
	[mm]	*[mm]*	*[mm]*	*[g]*	*[L]*	*[g/L]*
1	217.5	372.5	52.5	480.5	3.9	121.7
1	220.0	455.0	39.3	493.5	3.7	134.0
1	215.0	575.0	48.8	668.5	5.7	117.2
2	220.0	750.0	48.8	944.0	7.5	126.2
2	220.0	890.0	58.8	1026.0	10.8	95.1
2	220.0	1130.0	52.5	1407.0	12.4	113.6
					Average	117.9
					Standard deviation	13.3

Figure 4-5 shows an example for a prototype with two compartments provided. Unfortunately, it was not possible to get samples that are less filled and with a shorter length.

Figure 4-5: Prototype provided by company (b).

The company stated that theoretically a width of maximum 550mm with another machine would be possible. A height of 100-150mm would be with the existing machine feasible but the filling would not be uniform. A new development of the feeding of the filling material would be a possible option. A uniform filling of rather wide and short pouches might be feasible with the filling via several screw feeders instead of just one or with a vibrator (Personal communication, June 2020). As the uniformity of the material is a factor influencing the insulation capabilities of the pouch, it will be crucial to achieve a uniform filling. There was no other company found in time that was able to produce pouches in the wished dimensions with a VFFS machine. A development of a new filling technique that would secure a uniform filling of the insulation material in a rather wide and short pouch was out of scope.

Switching to a solution with only two compartments might be a possibility that could be further investigated, which was not possible in the given time frame. The delivered samples were too tight filled to build a pouch. It is most likely that less filled pouches will not be uniform anymore and would provide a poor insulation.

4.3 Production Feasibility Assessment

Before looking into the environmental and economical impact of the in-house production of insulation material for the meal-kit industry it needs to be examined, if the production would be feasible from a technical and organizational point of view.

4.3.1 Alternative 1

Two different production possibilities were identified in the research for the cooling pouch existing of multiple layers of cellulose and an outer and inner layer of spunbond.

1. Purchase of sheets in the right size
2. Purchase of cellulose and spunbond on rolls

For the first option would only a workstation be needed that facilitates the layering of the sheets and following sewing of the pouches. For the second option a workstation would be needed which holds the rolls of paper and spunbond. The cutting could be done automatically or manually. In the production facility of HelloFresh in Germany there are workstations that were meant to produce PET pouches (see Figure 4-6). It can hold several rolls of PET wool, which was perforated. The wool was pulled through a gap in front of the roll and ripped off at the perforation. On the table in front of the did the sheet get folded and put in a plastic bag, which was then pushed inside.

Figure 4-6: Workstation for PET pouch production.

Since HelloFresh switched to paper-based cooling pouches the working stations are no longer in use. It would favour the sustainability idea of this project to incorporate these workstations in the in-house production of cooling pouches as these racks will be not in use anymore and they could be reused. A cutting device would need to be added to the working station and the sewing machines would need to be connected in series. Due to the pandemic and time restrictions the focus of the research was placed on the sewing machine and the supply of the raw material. Unfortunately, it was not possible to find a supplier for an automatic cutting, folding and sewing machine. That would be a custom-made machine. Companies for such a solution were contacted but it was not possible to get enough information in time. For the calculations of the environmental and economical impact of the sewing step in the production alternatives was an internet research conducted and a sewing machine as representative chosen. A double head sewing machine was chosen appropriately like in Figure 4-7. Such a machine can stitch the pouch with 2,200 stitches per minute (Pfaff, 2020). For the sewing of the pouches are between 33 and 40 stitches needed. The maximum running speed of the sewing machine might be too fast to handle for the operator. Thus, a lower machine capacity than usual was chosen with 60%. To produce the weekly demand of insulation pouches would the sewing machine need to run for 40 hours per week. With a production capacity of five days in two shifts, it would be possible to produce the amounts with only one sewing machine (see Table 10).

Table 10: Machine capacity of sewing machine.

	Unit	*S*	*M*	*L*
Length	mm	350	390	420
Stitches	Stitches/pouch	33	37	40
Machine capacity	Stitches/min	2,200	2,200	2,200
	Pouches/min	40	36	33
	Pouches/h	2,400	2,154	2,000

Figure 4-7: Sewing machine for the production of paper pouches (Pfaff, 2020).

The sourcing of the raw material showed that the cellulose sheets are not a common paper and there are barely companies providing such a paper that exists of recycled material rather than virgin fibres. Nevertheless, the material is comparable to absorbent pads used in the hygiene industry. One company in Germany was found that was able to look further into a cooperation with HelloFresh to produce in-house insulation pouches. Due to the thickness of the material it was recommended to purchase the material already in layers on a roll.

As HelloFresh is using pouches with different layers of cellulose, there would be three options:

1. Rolls with lowest common denominator of layers
2. Rolls with final number of layers
3. Rolls with final number of layers and fixed width

The highest flexibility would the first option offer, because only three types of rolls in the fitting width would need to be purchased. The production could be dynamically be fitted to the weather forecast. The second option would mean that six different types of rolls need to be purchased, which would reduce the flexibility aimed for with the in-house production. The third option would be that the pouch has a fixed width and is just changing in height. There it would be again just three types of rolls needed. This option might cause implications in the box. The pouch is added standing in the box. If the pouch just changes in height but not width it would mean that the pouch gets too high for the box. E.g. the S and M box share the same height and just differ in width. Therefore, might the M pouch with more height getting too high for the box. Because of the bulking of the pouch it can be higher than the box itself, when not filled. But there is not data available, how much higher is still fitting in the box. Before considering that option, it should be tested. Unfortunately, it was not possible to test this due to the time restrictions and no availability of samples.

4.3.2 Alternative 2

Although there was no machine found yet that is suitable to produce a pouch chain with the aimed dimensions, it is meaningful to calculate the amounts of raw material that would theoretically be needed to produce such a pouch solution. This way it can be evaluated, if this alternative should be further researched. The prototypes provided by company (b) showed an average filling capacity of 118 g/L of shredded paper. The measurement of the bulk density (see Table 11) resulted in 61 g/L for the paper shred, which is only about half of the filling capacity of the bags. This difference might be caused by the filling process and measuring method. The filling material might get more compressed than in the measurement. The measurement was conducted by letting the filling fall into a measuring cup and knocking the cup on the table to even it out until 200 mL respective 500 mL was reached. The tared cup was then measured with a kitchen scale. Therefore, no pressure was applied to the material. The measurement of the bulk density and the filling capacity itself might be prone to errors as well as no professional laboratory equipment could have been used due to the corona pandemic and missing access to a laboratory.

Table 11: Bulk density measurement of paper shred and CIF.

	Paper shred				*CIF*		
Volume	***Weight***	***Density***		***Volume***	***Weight***	***Density***	
[ml]	*[g]*	*[g/ml]*	*[g/L]*	*[ml]*	*[g]*	*[g/ml]*	*[g/L]*
200	12	0.060	60.0	200	12	0.060	60.0
500	29	0.058	58.0	500	34	0.068	68.0
200	16	0.080	80.0	200	13	0.065	65.0
500	33	0.066	66.0	500	34	0.068	68.0
200	10	0.050	50.0	200	13	0.065	65.0
500	30	0.060	60.0	500	33	0.066	66.0
200	13	0.065	65.0	200	12	0.060	60.0
500	31	0.062	62.0	500	32	0.064	64.0
200	11	0.055	55.0	200	12	0.060	60.0
500	27	0.054	54.0	500	31	0.062	62.0
Average		***0.061***	***61.0***	***Average***		***0.064***	***63.8***
Deviation		***0.0083***	***8.3***	***Deviation***		***0.0032***	***3.2***

The bulk density of the paper shred and the CIF are similar, but the paper shred shows a standard deviation that is more than double of the CIF. This reflects the heterogeneity of the paper shred. While most of the cellulose has a maximum size of 800 µm (Personal communication, March 2020) the paper shred can have a size of several millimetre. This results in a more inhomogeneous material, which might influence the insulation properties of the material. Due to the travel ban and time restrictions it was not possible to measure the insulation properties of the material and compare it.

For the calculation of the needed materials the density of 61 g/L was chosen as appropriate. For the choice of the thickness of the pouches was the alternative 3 chosen. These liners are filled with a similar looking material to the CIF and were already tested at HelloFresh. The liners have a thickness of 14 mm and the insulation was only satisfactory when used in two layers. Therefore, 22 mm were chosen for the theoretical calculation of filling material needed to produce insulation pouches in alternative 2. Table 12 shows the additional material needed to produce the pouches. The pouches by the second alternative would weigh over 70% more than the current pouch. This will not only influence the carbon impact of the finished HelloFresh box but might also impede the handling of the pouches in the pick and pack process.

Table 12: Required material of the alternative 2 pouches filled with paper shred.

Type	***Delta [%]***
S	***+72***
M	***+77***
L	***+77***

Another factor influencing the feasibility of the production of insulation pouches with a VFFS machine is the capacity of the machine and availability of cardboard in the facility. The producer gives a range of compartments per minute for the machine depending on the size of the pouch and the filling grade. For the calculation of the required number of machines to produce the necessary volumes of pouches had some assumptions to be done (see Table 13).

Table 13: Assumptions for the calculation of number of machines.

Category	***Assumptions***
Production capacity	2 shifts on 5 days
Size of compartments	150-200 mm
Number of compartments	S & M = 4 compartments L = 6 compartments

With the given time frame and machine capacity would be in the best case and the worst case several machines needed to produce the insulation pouches. Per machine is a space of about 24 m² (Personal communication, June 2020) plus 10 % extra for the distance between the machines, therefore a space of several hundreds of square meters would be needed in total for the machines. Additional space will be needed for the closing process of the pouches. Thus, a new space would need to be found. Especially regarding dust generation, the machines should be in a closed room so that the food cannot get contaminated.

The biggest advance in terms of the carbon impact of this alternative is the incorporation of waste material, particularly paper and cardboard. Thus, the amounts needed for the weekly production were calculated. About 15% of the weekly amount of wastepaper is available from packaging material of raw material at the production facility in Germany. Thus, most of the filling material would still need to be purchased.

4.3.3 Infrastructure

For the in-house production of cooling pouches an infrastructure for the process itself and for connecting the production process of the pouches with the production process of the boxes is needed. For Alternative 2, the production room needs ports for electricity and pressured air. The room should be at least five meter high (Personal communication, June 2020). A system for the collection of the cardboard resulting from the box production would be needed. Right now, the cardboard is collected in waste containers at the different kitting and assembly lines, which are then emptied in a bigger container for the transport to the recycling facility. If a hydraulic device for lifting and emptying the containers would be put in front of the pouch plant, they could be used onward. An automatic change-over system from the pouch plant to the pouch closing step would be favourable to save personnel costs. Unfortunately, it was not possible in the given time frame to find a suitable solution for the changeover, folding and closing of the pouch.

All processing alternatives need a storage of the raw material and finished pouches as well as a suitable container. As it is planned to produce the pouches just-in-time there are no huge storages needed for the finished product. Due to the old pouch production in Germany a container system for the finished pouches already exists. Figure 4-8 depicts such a roll container.

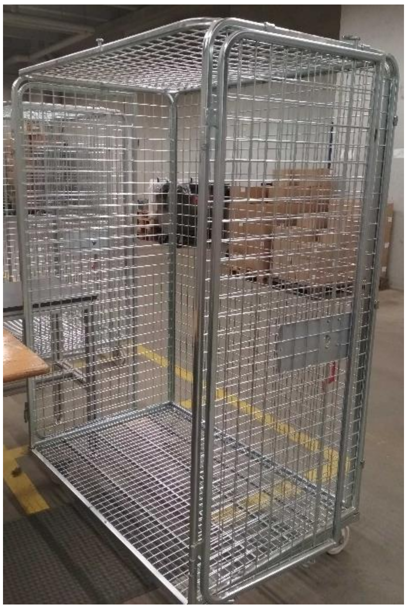

Figure 4-8: Roll container for finished pouches.

4.4 Environmental Impact Assessment

4.4.1 **Status quo and another supplier**

The first step of the environmental impact assessment was to calculate the CO_2-emissions of the status quo.

4.4.1.1 Scope 2 emissions

Table 14 shows the impact of the different production steps in the scope 2 emissions of the current pouch, in this case the local-based emissions. The raw material production is contributing with over 99% to the total scope 2 emissions of the pouch. The bigger the pouch, the higher the emissions.

Table 14: Local-based scope 2 emissions of current pouch.

	Unit	***S***	***M***	***L***	***Comment***
Weight	kg/pouch	60%	74%	100%	
Raw material production	kg CO_2e/pouch of total	99.86%	99.87%	99.90%	Production: Austria
Sewing step	kg CO_2e/pouch	0.14%	0.13%	0.10%	Production: Czech Republic
Total emissions	kg CO_2e/pouch	60%	74%	100%	

For the calculation of the scope 2 emissions for an alternative supplier only data for the place of production was given and the type of energy used. Thus, it was assumed that the production process and resulting energy usage is the same. The local-based emissions are nearly the same for both pouch alternatives. The market-based values are only 7% of the local-based emissions for the status quo. For the alternative purchased pouches are the market-based emissions about 300% higher compared to the actual pouch (see Table 15). The market-based emissions of the alternative pouches are 70% lower than the local-based emissions. See Appendix A.1 and A.2 for the calculations of the market-based numbers for the current pouch and the alternative pouch as well as the local-based numbers for the alternative pouch.

Table 15: Local-based and market-based scope 2 emissions of status quo and alternative supplier.

	Local-based emissions	***Market-based emissions***
	g CO_2e/pouch	g CO_2e/pouch
Status quo	100%	7%
Alternative supplier	99.99%	415%
Delta alternative supplier	-	30%

That there is nearly no difference in the local-based emission factor is caused through the production process of the raw material, which is consuming about 1000 times more energy than the sewing step. Both productions are placed in the same country and share the same emission factor. The difference in the market-based values originate from the fact that the status quo supplier is using 100% renewable energy while the alternative supplier is only using 75% renewable resources.

4.4.1.2 Scope 3 emissions

In Table 16 can an example for the difference in truckloads be seen, in this case for the finished product. For the transport of the biggest and thickest pouches can 40% less pouches be transported compared to the smallest and thinnest pouches. The tonnes per truck differ up to nearly 14%.

Table 16: Truckloads for the finished product.

Pouch size	***Pouches/truck***	***Additional tonnes/truck***
S light	100%	-
M light	80%	+1.8%
L light	70%	+13.7%
S normal	90%	+4.2%
M normal	70%	+1.0%
L normal	60%	+13.7%

Table 17 shows that the tonne-kilometres for the semi-finished product (a) are for both pouches nearly the same. For the transport of the semi-finished product (b) are the tonne-kilometres of the alternative purchased pouch about three times higher than the actual pouch but for the finished pouch (c) are the tonne-kilometres about nine times lower.

Table 17: Tonne-kilometres per truckload and transportation process for the actual pouch (see Appendix A.4 for detailed numbers).

Pouch size	*Raw material (a) (t-km)*	*Semi-finished product (b) (t-km)*	*Finished product (c) (t-km)*
Actual pouch	2,627	1,716	3,468
Another supplier	2,564	5,324	400

As the next step was the emission factor determined. Table 18 shows the ratio for the CO_2 emissions produced per transport process of the different pouch types. For the transportation of the raw material were the system boundaries only set for the recycled cellulose, but the fleece was excluded as it accounts for maximum 5% to the emissions and the conditions were not known. Most of the transport emissions, the finished product accounts for 41% on average, followed by the raw material with 38% and the semi-finished product with 21% in case of the current pouch. For the alternatively purchased pouch the average ratio of the transport of the raw material is 35% of the emissions like the actual pouch. The semi-finished product accounts for more with 61% and the finished product with only 4%.

Table 18: Ratio of CO_2-emissions per pouch per transportation process of the current pouch and pouch from another supplier (see Appendix A.3 for detailed numbers).

Alternative	***Ratio of CO_2-emissions per pouch per process***		
	Raw material (a)	*Semi-finished product (b)*	*Finished product (c)*
Current pouch	38%	21%	41%
Another supplier	35%	61%	4%

Table 19 shows the emissions of the different pouch types compared to the normal pouch in size S, which is the most used pouch. The emissions are higher the bigger and thicker the pouch is. While the light pouch in size S emits 16% less than the normal pouch does in size L emit 52% more than the normal pouch in the smallest size.

Table 19: CO_2-emissions of actual pouch relative to normal pouch in size S (see Appendix A.3 for detailed numbers).

Pouch type	*CO_2-emissions of actual pouch relative to normal pouch in size S*
S light	84%
M light	107%
L light	131%
S normal	*100%*
M normal	121%
L normal	152%

When getting into further contact with the other supplier for insulation pouches, it appeared that the raw material, the cellulose is produced in Austria as well. The waste cardboard is mainly sourced in Austria, therefore the furthest possible distance in Austria was taken for the calculation of the tonne-kilometres. As the light and extra light pouches are not yet offered by the supplier there was just limited data available for the truck loads. In that case was the data from the actual pouch taken, as it is the same material. The results show that the pouch from another supplier would create about the same amount of carbon emissions in the transport process for the raw material, but the transport for the semi-finished product would be about three times higher and the transport of the finished product would only account for 12% of the carbon emissions (see Table 20). This results in a total plus of 12% in the GHG emissions caused by the transport processes for the alternative purchased pouch.

Table 20: Average CO_2-emissions of alternative purchased pouch relative to actual pouch (see Appendix A.3 for detailed numbers).

CO_2-emissions relative to actual pouch			
a	*b*	*c*	***Total***
103%	320%	12%	**112%**

The results show that the emissions strongly depend on the size and thickness of the pouch. For the biggest and thickest pouch are the emissions about double of the smallest and thinnest pouch. This can be explained by the truck efficiency. When only fully laden trucks are taking the route to the destination more of the smaller pouches can be transported than of the bigger pouches. While the weight of the truck is about 12% higher than for the small pouches only 40% of the maximum number pouches can be transported. Thus, the tonne-kilometres are higher per pouch and therefore the CO_2-emissions.

The GHG emissions for the pouch purchased from another supplier, that has its production in Germany, are higher than for the supplier with its production in Austria and Czech Republic. That was not expected in the first place as it was not known that the production of the semi-finished product is in Austria as well. When comparing the transport of the finished product are the emissions much lower than for the actual supplier. But due to the further transport of the raw material and the semi-finished product are the average greenhouse gas emissions per pouch purchased from this supplier slightly higher than for the actual pouch. Therefore, it would not be more favourable to switch to another supplier from an environmental impact point of view.

4.4.2 **Alternative 1**

4.4.2.1 Scope 2 emissions

For the calculation of the scope 2 emissions for the first alternative was the same production process and energy consumption assumed as the status quo. The raw material is produced with one third renewable energy in Germany and the sewing step is done at the production facility of HelloFresh where 100% renewable energy is purchased. Table 21 shows that the sewing step only has a marginal impact on the scope 2 emissions of the production alternative 1 and that the market-based scope 2 emissions of production alternative 1 are 32% lower than the local-based emissions.

Table 21: Local-based and market-based scope 2 emissions alternative 1.

	Local-based emissions	***Market-based emissions***
Raw material production	99.952%	99.998%
Sewing step	0.048%	0.002%
Total	**100%**	**68%**

This result shows that the main impact on the GHG emissions through the production process are resulting from the production process of the recycled cellulose and that the sewing steps have only a marginal impact on it.

4.4.2.2 Scope 3 emissions

For the first production alternative are both raw materials, the recycled cellulose and the fleece, no standard products in the aimed format offered by the contacted suppliers. Therefore, no exact data for truckloads for the different pouch sizes was given. Thus, it was just possible to calculate the average tonne-kilometres for a uniform pouch size for the transportation processes with the given average laden of the truck. Table 22 shows that the tonne-kilometres for the transportation of the spunbond are the highest with about 3,600 t-km, for the wastepaper it is about

2,300 t-km and for the recycled cellulose about 1,000 t-km. The transport of the raw material for the spunbond was again excluded due to missing data and its low percentage in the finished pouch.

Table 22: Tonne-kilometres per truckload and transportation process for alternative 1 (see Appendix A.3 for pre-step calculations).

Pouch size	***Spunbond (t-km)***	***Wastepaper (t-km)***	***Recycled cellulose (t-km)***
uniform	3,604	2,250	1,098

Table 23 shows the ratio of greenhouse gases emitted by the transport process of the spunbond to the production facility (a), the wastepaper to the supplier (b-1) and the recycled cellulose to the production facility (b-2). The first step is producing the lowest amount of emissions with only 1% of the total emissions. The transport of the wastepaper to the production for the recycled cellulose is emitting the most with 70%. The last step makes 29% of the total emissions.

Table 23: Ratio of CO_2-emissions per in-house produced pouch via alternative 1 by transport step.

	a	***b-1***	***b-2***
CO_2-emissions of total	1%	70%	29%

The results show that the emissions by transportation processes of the first alternative are only 40% of the emissions released through the transportation processes of the actual pouch. This can be explained by the truck filling rates. While in the status quo process are already semi-finished and finished products transported, are in the first alternative only the raw materials transported. This way fits more material for the pouches on the truck and the environmental burden of one pouch gets lowered.

4.4.3 **Alternative 2**

4.4.3.1 Scope 2 emissions

To calculate the emissions caused by the production of the product were to scenarios chosen. Because the machine output is not exactly sure yet and only a range is available were the emissions calculated for the worst-case output and best-case output. Table 24 shows that the emissions are in the worst-case nearly double of the best-case scenario. The market-based emissions are significantly lower than the local-based emissions with only 2-3%.

Table 24: Local-based and market-based emissions for production alternative in worst case and best case (see Appendix A.1 & A.2 for detailed calculations).

	Local-based emissions	***Market-based emissions***
	g CO_2e/pouch	g CO_2e/pouch
Alternative 2 – worst case	100%	3%
Alternative 2 – best case	52%	2%

The huge difference from market-based emissions to local-based emissions can be explained by nearly complete in-house production of the raw material and the purchase of 100% renewable energy. While the local-based emission factor for Germany accounts with 0.7 kg CO_2e/kWh, is the emission factor for hydropower only 0.024 kg CO_2e/kWh (Covenant of Mayors, n.d.).

4.4.3.2 Scope 3 emissions

To produce the pouch with the second alternative are different scenarios possible. The pouches could be filled with two different materials, either a CIF (a) offered by a Company in Germany. The other option would be a paper shred (b) that is with 15% from the wastepaper in the production facility and the rest could be supplied by a trader for wastepaper. As it was not possible to find out how the transportation modalities will be, a truckload of 20 tonnes were assumed. Two different paper film suppliers gave information about their product, which could be used for the carbon impact analysis. The first supplier (c) offers a paper film in a thinner quality with 65 g/m² and has its production in Germany. The second supplier (d) offers a paper film with 110 g/m², which results in a higher number of tonne-kilometres (see Table 25).

Table 25: Tonne-kilometres per truckload and transportation process for alternative 2 (see Appendix A.3 for detailed calculations).

Pouch size	***a*** (***t-km***)	***b*** (***t-km***)	***c*** (***t-km***)	***d*** (***t-km***)
uniform	4,950	2,560	15,617	23,414

Table 26 shows the ratio of the average CO2-emissions per pouch released per transportation process of the raw material. The transport of the CIF emits most GHG, while the emissions from the transport of the wastepaper and the thick paper film are about a quarter of the CIF and the thin paper film only 9%.

Table 26: Ratio of average CO_2-emissions per transportation process for the raw material of alternative 2 (see Appendix A.3 for detailed numbers).

	a (CIF)	***b (wastepaper)***	***c (paper film, thin)***	***c (paper film, thick)***
Average CO_2-emissions	100%	28%	9%	22%

Although not every combination might be possible to produce on the given machine, all four scenarios were calculated (see Table 27). A pouch made of the CIF insulation material and the thick paper film would emit most. The CIF with a thin paper film would emit 11% less. The least emissions would be set free by the transport of the raw material when combining the paper shred with a thin paper film, which only accounts for 30% of the combination a/d. With a thicker film would the emissions be 11% higher.

Table 27: CO_2-emissions per in-house produced pouch via alternative 2 per production scenario.

	AverageCO2-emissions	
	c	*d*
a	89%	100%
b	30%	41%

The most favourable scenario would be a production of pouches with paper shred filled in a paper film supplied by company b, which only emits 30% of the worst-case scenario. This can be explained through the lowest numbers of tonne-kilometres. Additionally, just 85% of the emissions go into the pouch for the paper filling as the rest is sourced in the own production. Although it is sourced in the production, the wastepaper was once transported to HelloFresh, but the system boundaries were only set for the raw material used to produce the pouch. The production of the virgin material, the paper film and the paper, which is purchased as wastepaper, was excluded and would have been out of scope.

4.4.4 Overall Environmental Impact

Table 28 depicts the impact of the emissions caused by the production compared to the emissions caused by the transportation processes. For the actual pouch and the pouch purchased from another supplier is the impact of the change from local-based numbers and market-based numbers similar. Due to the change in the emissions through the production the impact of the transport becomes higher although the numbers themselves do not change. The highest impact can be seen in the second alternative where the impact through transportation gets higher than the impact through the production.

Table 28: Overview of local-based and market-based environmental impact contributors of production alternatives for insulation material for meal-kits.

	Local-based		*Market-based*	
Alternative	***Transport***	***Production***	***Transport***	***Production***
Actual pouch	56%	44%	95%	5%
Another supplier	59%	41%	83%	17%
Alternative 1	18%	82%	25%	75%
Alternative 2	4%	96%	56%	44%

Table 29 shows that when considering the local-based emission factors all alternatives to the actual purchased pouch emit more carbon dioxide. Alternative 2 emits the most with about 66% more than the actual pouch, while the pouch purchased from another supplier shows the lowest number with about 7% extra. When looking at the market-based numbers the pouch by the alternative supplier emits 29% more GHG than the actual pouch, while the first alternative emits 53% more. Only the second alternative would save emissions with 79%.

Table 29: Overview of local-based and market-based environmental impact of production alternatives for insulation material for meal-kits compared to actual pouch.

Alternative	***Market-based CO_2-emissions***	***Local-based CO_2-emissions***
Another supplier	+7%	+29%
Alternative 1	+23%	+53%
Alternative 2	+66%	-79%

The environmental impact analysis shows that the carbon emissions through transport are lower for the in-house production alternatives but the emissions through production are higher on a local-based level, thus the overall emissions are higher for the in-house produced pouches compared to the actual purchased pouch.

Whereas the carbon emissions are much lower for the production when produced with 100% renewable energy like in the market-based scenario (see alternative 2 in Table 29). This shows that the environmental impact of the in-house production depends strongly on the place of production and the emission factors. There cannot be a general recommendation be given, if the environmental impact of the in-house production of insulation material for the meal-kit industry is better or worse compared to an external purchased solution. It needs to be examined for each individual case, what's the most favourable alternative. In the case of HelloFresh with the production in Germany an in-house production of insulation material with the second alternative would be more favourable when looking at the market-based numbers. As the place of production is already existing and not changeable it is more a decision, which could influence the grid mix.

4.5 Cost Impact Assessment

4.5.1 Equipment Outputs

The first step of the cost calculations was to calculate the equipment outputs for the different production alternatives. To produce the pouches with the first alternative is mainly a sewing machine needed that sews the pouches from both sides. Table 30 shows the calculated equipment output of production alternative 1 used for the impact cost assessment. One machine is enough to meet the weekly demand.

Table 30: Equipment output of production alternative 1.

Equipment Output	***Alternative 1***
Output (Stitches) / Min	2,200
Output (Stitches) / Hour	132,000
Machine Efficiency	60%
Output (Stitches)/ Machine / Hour Efficiency	79,200

For producing the pouches with the second alternative, the bottle neck would be the pouch forming step with the cardboard recycling plant. Since it is not yet determined what the actual output of the machine will be, it was calculated with the worst case. As the available production time is limited to five days with two shifts per day is the maximum available production time 80 hours. If the production capacity cannot be extended, the number of machines needs be extended. Several machines would be necessary.

4.5.2 **Fixed Costs**

For the calculation of the fixed costs are the investment costs crucial. If no number was given by the machine producer for the different positions a reasonable number was taken from similar business cases at HelloFresh. Due to the number of the machines are the investment costs for the second production alternative about 3 times higher than for the first alternative (see Appendix B.1). By calculating the depreciation can the investment costs be allocated to the product. For the calculation of the depreciation was a useful lifetime of five years chosen.

4.5.3 **Variable Costs**

The variable costs per pouch consist of different factors, the costs for the material, labour costs, energy costs and costs for the service and maintenance. The raw material costs depend on the size and thickness of the pouch. For the calculation of the raw material costs of the first alternative it was chosen to only take the 32-layer pouch to reduce the complexity and facilitate the comparability to the second alternative. Table 31 shows that the film makes about 3-4% of the weight of the total pouch in both production alternatives. The price of the film for the second alternative, which is a paper film, is about 50% lower per tonne than for the first alternative, which is a spunbond material, but the spunbond only represents about 7% of the total raw material costs, while the ratio is about 36% in average higher for the paper film in the second alternative. Respectively account the filling costs for the first alternative for about 93% in average and for the second alternative for about 64% of the total raw material costs per pouch.

Table 31: Variable costs for the different production alternatives.

Variable Costs		**Alternative 1**	**Alternative 2**
Ratio Film / Pouch		4%	3%
Price Film / to		*100%*	*50%*
	S	6.47%	36.04%
Total Cost Film / Pouch	M	6.62%	35.94%
	L	6.60%	35.78%
Average		7%	36%
Ratio Filling / Pouch		96%	97%
Price Filling / to		*100%*	*6%*
	S	93.53%	63.96%
Total Cost Filling / Pouch	M	93.38%	64.06%
	L	93.40%	64.22%
Average		93%	64%

The labour costs depend on the number of operators needed and the running hours per week. For the first production alternative it is assumed that one qualified operator for running the sewing machine and one unqualified operator for packing the finished products is enough. For the second alternative it is assumed that two qualified and three unqualified operators are needed to run the nine machines as the main process is running automated. The sewing machine is just running half as long as the cardboard plant and less operators are needed. This results in 61% higher labour costs for the second alternative (Table 32).

Table 32: Labour Costs for the different production alternatives.

Labour Cost - Production	***Alternative 1***	***Alternative 2***
Hours / Week	100%	200%
Employees / Machine qualified	100%	33%
Employees / Machine unqualified	100%	33%
Total paid hours	100%	567%
Hourly rate qualified labour	100%	100%
Hourly rate unqualified labour	76%	76%
Total Labour Cost / Week	100%	161%

Table 33 shows that the second alternative is using much more energy and needs more operating hours than the first alternative resulting in 330,000% higher energy costs per pouch.

Table 33: Energy costs for the different production alternatives.

Energy Cost - Production	***Alternative 1***	***Alternative 2***
kWh per operating hour	100%	30769%
Machine Operating Hours / Week	100%	1075%
Total Production Energy Cost / Week	100%	330654%

Table 34 depicts that the second production alternative accounts with 630% more costs for spare parts, resulting in 327% more costs for service and maintenance per year in total.

Table 34: Service and maintenance costs for the different production alternatives.

Service and Maintenance - Production	***Alternative 1***	***Alternative 2***
Spare parts / Year	100%	630%
Service contract / Year	100%	100%
Total Service and Maintenance / Year	100%	327%

The calculations of the variable costs showed that the filling for the first alternative is accounting most for the total raw material costs. This is caused by the high ratio of filling. For the second alternative is the paper film account with 30% more to the costs. This can be explained by the lower cost of the filling, which is paper shred made from wastepaper partially sourced from the production facility, which only makes 6% of the price per tonne compared to the CIF filling. The higher labour, energy, service and maintenance costs from the second alternative compared to the first alternative are caused by the complexity and number of the machines. While for the first alternative just a sewing machine is needed, which shows a low energy consumption, does the second machine require several machines that are more complex. Thus, it requires more personnel, energy and maintenance.

4.5.4 **Overall Costs**

Table 35 shows the overall costs of production alternative 1 and 2. The fixed costs of the first production alternative contribute with around 3-4% to the total costs of the pouch. For the second production alternative are the fixed costs higher with 30-38%. The total investment costs are about 3.4 times higher for the second alternative than for the first one. Respectively do the variable costs contribute with 96-97% for alternative 1 and 62-70% for alternative 2. For the first alternative is the raw material with over 93% the main contributor to the total costs. The raw material of the second alternative is only contributing with 35-48% to the total costs. But the labour, energy and maintenance costs are higher.

Table 35: Contributors to the total costs of production alternative 1 and 2.

	Alternative 1			***Alternative 2***		
	S	*M*	*L*	*S*	*M*	*L*
Volume (Pouches/Week)	50%	30%	20%	50%	30%	20%
Total Investment Cost		100%			341%	
Depreciation per year		100%			341%	
Fixed costs per pouch	**4%**	**3%**	**3%**	**38%**	**34%**	**30%**
Total Raw Material Costs / Pouch	93%	94%	95%	35%	41%	48%
Total Labour Cost / Pouch	3%	3%	2%	13%	12%	11%
Total Energy - Production Cost / Pouch	0.002%	0.001%	0.001%	12%	11%	9%
Total Service and Maintenance / Pouch	0.2%	0.2%	0.1%	1.8%	1.6%	1.4%
Total variable cost/pouch	**96%**	**97%**	**97%**	**62%**	**66%**	**70%**

Table 36 shows that both production alternatives would generate savings compared to the actual pouch. The first alternative would save about 40% and the second alternative would save 86% of the costs. The break-even point would be reached earlier in the first alternative with 43% less pouches than the second alternative.

Table 36: Total costs and savings of production alternative 1 and 2 compared to the price of the actual pouch.

	Alternative 1			***Alternative 2***		
	S	*M*	*L*	*S*	*M*	*L*
Total Savings/Pouch	41%	39%	33%	78%	79%	80%
Margin Saving/Pouch	43%	41%	35%	86%	86%	86%
Annual savings after BEP		**40%**			**86%**	
Break even period (pouches)		57%			100%	

Table 37 depicts the percentual additional costs for the 32-layer pouches of another supplier compared to the pouches of the actual supplier. The pouch would cost between 14 and 26% more per pouch, which would generate 22% additional costs per year.

Table 37: Additional costs of insulation pouches of another supplier compared to actual supplier.

		Another supplier	
	S	*M*	*L*
Volume (Pouches/Week)	50%	30%	20%
Additional costs	**26%**	**21%**	**14%**
Additional cost/year		**22%**	

The calculation of the carbon offsetting charges shows that on a local-based calculation there would be additional costs created between 0.005% and 0.044% more of the total costs of the actual pouch (see Table 38). For a market-based calculation would be for the purchase of the pouch from another supplier be 0.012% additional costs created. The in-house production with alternative 1 would create 0.021% additional costs. The in-house production would save 0.030% carbon offsetting from the total costs. Nevertheless, when comparing the annual savings or additional cost from the cost impact assessment to the total annual additional costs/savings the carbon offsetting has nearly no impact on the cost calculation.

Table 38: Local-based cost comparison.

Alternative	*CO_2-emissions* [toCO2e/ year]	*Savings/additional cost through carbon offsetting of total cost of actual pouch* [€/year]	*Total annual additional costs/savings* [€/year]
Another supplier	+7%	+0.005%	+22%
1	+23%	+0.015%	-40%
2	+66%	+0.044%	-86%

Table 39: Market-based cost comparison.

Alternative	*CO_2-emissions* [toCO2e/ year]	*Savings/additional cost through carbon offsetting of total cost of actual pouch* [€/year]	*Total annual additional costs/savings* [€/year]
Another supplier	+29%	+0.012%	+22%
1	+53%	+0.021%	-40%
2	-79%	-0.030%	-86%

The cost impact assessment shows that a purchase of the same pouch type from another supplier would not be favourable as it would create additional costs. But the assessment shows that an in-house production of insulation material for meal-kits would be favourable from the economical impact view. Both considered production alternatives would generate annual savings. The second production alternative would need eight weeks longer for the break-even point but would create about three million euros per year more savings. Thus, the second alternative would be the most favourable option. Nevertheless, is the cost impact assessment only a rough overview of the estimated costs and is based on many assumptions and only rough price indications. For a strategic decision should be a more detailed cost calculation with exact numbers be conducted.

4.6 Comparison of all Factors

Table 40 depicts the ranking of the different production and purchase alternatives for insulation material for the meal-kit industry based on the local-based numbers. In this case would the status quo, the purchase of insulation pouches, which are produced in Austria and Czech Republic, be the most favourable alternative with a score of ten points. The purchase of the insulation pouches from another supplier and the second in-house production alternative would with a score of six be the least favourable alternatives.

Table 40: Assessment ranking of all factors on local-based numbers.

Production alternative	*Feasibility Assessment*	*Environmental Impact Assessment*	*Cost Impact Assessment*	*Overall ranking*
Status quo	4	4	2	**10**
Another supplier	3	2	1	**6**
1	2	3	3	**8**
2	1	1	4	**6**

When comparing the market-based values does the second production alternative show the highest score with nine points. Purchasing from another supplier would again result in the lowest score with five points (see Table 41).

Table 41: Assessment ranking of all factors on market-based numbers.

Production alternative	*Feasibility Assessment*	*Environmental Impact Assessment*	*Cost Impact Assessment*	*Overall ranking*
Status quo	4	2	2	**8**
Another supplier	3	1	1	**5**
1	2	3	3	**8**
2	1	4	4	**9**

The comparison of all factors shows that the purchase of the pouch from another supplier that is producing in Germany would result for HelloFresh in a worse carbon impact and higher costs. Therefore, this option is not recommended in that case. Generally, it depends on the place of the production and where the supplier is sourcing its raw material, if another supplier would be the better choice. When there are different suppliers available it is worth it to conduct an environmental impact analysis to find the most sustainable solution.

If the in-house production of insulation material is more sustainable than the purchase cannot be generally said. The environmental impact is complex and dependent on many different factors, e.g. where the raw material is purchased and where the finished pouch is produced. Thus, it cannot a general recommendation be given, and it must be checked for each case individually. In the case of the HelloFresh production in Germany, it would be a more sustainable process on a market-based view. For the cost impact assessment, the result is clearer. An in-house production of insulation material would most likely result in a cost reduction. Both production alternatives showed savings after the break-even point. Here showed the second alternative, the production of pouches with a VFFS machine, the most promising results. Although the cost impact assessment is just a rough assessment of the costs for the pouches produced with this alternative, it can be an indication for the positive impact of the in-house production from an economical point of view and that further research should be invested in the evaluation of the feasibility of the second production alternative. Unfortunately, that alternative is not a concept that is on the market yet. It is not clear if this solution will deliver satisfactory insulation properties. The second point lowering the feasibility of that option is that quite a lot of machines are needed for the production to cover the needs of a meal-kit company the size of HelloFresh. Such a high number of machines need a lot of space and a separate production room due to the dust in the building. These may implement costs that are not yet considered in the cost calculation and might not be an option for already existing meal-kit productions due to the lack of available space.

Concluding it can be said that the in-house production of insulation material for meal-kits can have a positive environmental and economical impact. Depending on where the actual pouches are purchased and where the raw material would be purchased and the finished product be produced, the GHG emissions will be lower. This could be for example the case for the HelloFresh production in Sweden, where the same pouches as in Germany are produced. If a supplier for the raw material in Sweden were close to the facility, the environmental impact will most probably lower due to the shorter transport distances and the lower local emission factors. It is recommended for HelloFresh to conduct further research on the insulation properties and the environmental and economical impact for the other countries.

5 Conclusions

For a conclusion of the study the research questions are answered in this chapter. Moreover, the delimitations of the study are discussed, and further research recommendations given.

5.1 Research Questions

The following research questions were asked in the study and answered by the researcher.

RQ1: What is the impact of an in-house cooling pouch production on the production process at HelloFresh?

The evaluation of the in-house production of insulation material for the meal-kit industry showed that there are different production processes conceivable. Two production processes were chosen to be examined. The first process is resulting in the same pouch type that is used currently at HelloFresh. The raw materials would be purchased, cut and sewed to a pouch that consist of several layers of cellulose paper and a spunbond as outer and inner layer. This alternative shows a high grade of feasibility as it is an already existing concept on the market and used at HelloFresh. The insulation properties of the material are already known and used. One cutting, folding and sewing machine will most probably be enough to cover the demands of a company in the size of HelloFresh. Thus, not much space in production is needed.

However, the second production alternative would be a more innovative process with a new pouch type as a result. With a VFFS machine a pouch chain is made from paper film and paper-based insulation filling produced which is subsequently folded and sewed together to an insulation pouch. Due to its innovative character was a prototyping process conducted, which could not be finished due to time restrictions. Thus, the insulation properties could not be tested. Nevertheless, the production modalities were examined. This process would need a rather high number of machines to meet the demands and the production would need to be separated from the meal-kit production due to the high dust exposure. Therefore, an implementation of the process is complex, and it cannot be concluded from this study, if this production process would result in a satisfying insulation pouch.

RQ2: How is the environmental impact of an in-house produced cooling pouch compared to a purchased cooling pouch?

For the evaluation of the environmental impact of cooling pouches additionally to the in-house production a purchase from another supplier was examined to show the influence of the transport and production processes on the environmental burden of a product. The evaluation showed that it is not possible to give a general recommendation whether the in-house production of insulation material leads to a reduction of environmental impacts compared to the status quo. The GHG emissions caused by an insulation pouch depend on the purchase regions of the raw material, transport modalities, the place of production and the local- and market-based emission factors, but this study gives an indication that the in-house production of insulation material for the meal-kit industry can lower the emissions. In case of the production facility of HelloFresh in Germany an in-house produced pouch would result in lower carbon emissions from a market-based point of view. The lower carbon emission results from the purchase of renewable energy and the local sourcing of the raw material, which is partly reused wastepaper from the production facility.

RQ3: How is the economical impact of an in-house produced cooling pouch compared to a purchased cooling pouch?

The evaluation of the economical impact displayed a clearer result than the environmental impact assessment. Both production alternatives would result in a reduction of the costs per pouch. After reaching the break-even point in a reasonable time would both alternatives create savings; the second alternative would create the most savings.

Overall, it has been concluded that the environmental and economical impact of the in-house production of insulation material for the meal-kit industry cannot be generalized and needs to be examined for the individual cases. Especially the GHG emissions caused by the in-house production depend on complex factors. But the study gives an indication that the in-house production of insulation pouches might generate lower emissions and create savings.

Considering all aspects, it is recommended for HelloFresh to conduct further research to evaluate the in-house production with a VFFS machine to produce insulation pouches based on a pouch chain from paper film filled with paper-based insulation material.

5.2 Delimitations

Although the study gives an indication for the environmental and economical impact of the in-house production for insulation material, the study is limited to one single case. Due to time restrictions the study had to be limited to the purchase, production and usage of insulation pouches in Germany for HelloFresh. Other companies and countries were not examined, which could have a huge impact on the results. The study can therefore not be used as a statement for other countries. It can only be used to get an idea about the influencing factors and to facilitate the evaluation of other cases.

The environmental impact evaluation was simplified to a carbon impact assessment including only the emission caused by transportation of direct raw material and energy consumption through the production. Thus, the carbon emissions calculated are only relative numbers. For an exact value of the carbon emission a complete Life Cycle Assessment would be necessary. This would include all factors contributing to the carbon emissions of a product, e.g. for a recycled material the emission through the production of the virgin material. This was excluded from the study. Additionally, were assumptions taken where data was missing.

The economical impact evaluation was reduced to the most important factors and is only a rough calculation of the cost of a pouch produced with an alternative process. A lot of data is based on rough estimations from suppliers or assumptions from other case studies at HelloFresh. Especially the data for the raw material, which is needed to produce the pouch, is based on data from an incomplete prototyping process conducted with no professional equipment due to the ongoing pandemic. Thus, are the numbers based on a rather high uncertainty.

5.3 Review of the Case Study

This study was conducted while a worldwide pandemic was ongoing resulting in some restrictions for the case study. Due to the travel and contact ban it was not possible to conduct tests in the international test laboratory or the university. Thus, it was not possible to conduct tests on the material which is crucial for the evaluation whether the material is suitable as insulation material. Although a lot of data was missing it was possible to conduct a theoretical analysis which gives an indication for the sustainability of an in-house production of insulation material for the meal kit industry. Due to the exceptional situation it was decided to break down the analysis to only one country. The study would have been more informative if the in-house production would have been compared between different countries.

5.4 Further steps

The recommendations developed in this case study are predominantly from theoretical considerations. The prototyping process from the second production alternative needs to be continued and the thermal performance of this pouch type should be tested. The following steps should be conducted.

- Build pouches in the aimed sizes
- Test different pouch thicknesses
- Thermal performance test with liner
- Thermal performance test with pouch

While this project was conducted it was not possible to test the insulation properties of the developed pouch ideas. Thus, it is crucial to build a prototype in the target size that can be tested for its insulation properties. In the first step the pouches filled with paper shred could be tested as a liner to get an idea how much material is needed.

The production and filling processes are to be developed further to check the feasibility of the process. Specifically, for the second processing alternative more data needs to be collected and an evaluation for other countries be conducted to examine if a further development process should be conducted. The following points should be reviewed.

- Filling process from shredder to pouch
- Pouch forming step (e.g. sewing)
- Automated connection from VFFS machine to pouch forming step

As the aim is to produce a rather wide and short pouch it is not possible to achieve such a format with the existing machinery. Thus, a filling solution, e.g. several screw fillers, needs to be developed and tested. The pouch forming step needs to be further elaborated, e.g. if sewing is possible and what kind of machines and material are needed. A connection between the VFFS machine and the pouch forming step is not yet considered and would be done manually but there might be an option to automate the process.

A further data collection based on the prototyping process and process development for the cost impact assessment is necessary as well, to get a more precisely calculated price for the in-house produced pouches. The following points should be considered for a more detailed analysis.

- Amount and prices of raw material
- Equipment costs
- Feasible machine capacity
- Necessary employees/machine
- Automation, Internal Transport, HF Infrastructure etc.
- Energy consumption
- Service and maintenance

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Appendix A – Environmental Impact Assessment

Local-based and market-based scope 2 emissions calculations, transportation modalities

A.1 Local-based Scope 2 Emissions Calculations

Table 42: Local-based scope 2 emissions of alternative pouch.

	Unit	***S***	***M***	***L***	***Comment***
Weight	kg/pouch	60%	74%	100%	
Raw material production	kg CO_2e/pouch of total	99.88%	99.89%	99.91%	Production: Austria
Sewing step	kg CO_2e/pouch	0.12%	0.11%	0.09%	Production: Czech Republic
Total emissions	kg CO_2e/pouch	60%	74%	100%	

Table 43: Local-based scope 2 emissions of alternative 1.

	Unit	***S***	***M***	***L***	***Comment***
Weight	kg/pouch	60%	74%	100%	
Raw material production	kg CO_2e/pouch of total	99.95%	99.95%	99.96%	Production: Germany
Sewing step	kg CO_2e/pouch	0.05%	0.05%	0.04%	Production: Germany
Total emissions	kg CO_2e/pouch	60%	74%	100%	

Table 44: Local-based scope 2 emissions of alternative 2 in worst case.

	Unit	***S***	***M***	***L***	***Comment***
VFFS machine	kg CO_2e/pouch of total	99.97%	99.97%	99.98%	Production: Germany
Sewing step	kg CO_2e/pouch	0.03%	0.03%	0.02%	Production: Germany
Total emissions	kg CO_2e/pouch	67%	67%	100%	

Table 45: Local-based scope 2 emissions of alternative 2 in best case.

	Unit	***S***	***M***	***L***	***Comment***
VFFS machine	kg CO_2e/pouch of total	99.94%	99.93%	99.95%	Production: Germany
Sewing step	kg CO_2e/pouch	0.06%	0.07%	0.05%	Production: Germany
Total emissions	kg CO_2e/pouch	66%	66%	100%	

A.2 Market-based Scope 2 Emissions Calculations

Table 46: Market-based scope 2 emissions of current pouch.

	Unit	***S***	***M***	***L***	***Comment***
Weight	kg/pouch	60%	74%	100%	
Raw material production	kg CO_2e/pouch of total	98.04%	98.23%	98.58%	Production: Austria
Sewing step	kg CO_2e/pouch	1.96%	1.77%	1.42%	Production: Czech Republic
Total emissions	kg CO_2e/pouch	60%	74%	100%	

Table 47: Market-based scope 2 emissions of alternative pouch.

	Unit	S	M	L	Comment
Weight	kg/pouch	60%	74%	100%	
Raw material production	kg CO_2e/pouch of total	99.99%	99.99%	99.99%	Production: Austria
Sewing step	kg CO_2e/pouch	0.01%	0.01%	0.01%	Production: Czech Republic
Total emissions	kg CO_2e/pouch	60%	74%	100%	

Table 48: Market-based scope 2 emissions of alternative 1.

	Unit	S	M	L	Comment
Weight	kg/pouch	60%	74%	100%	
Raw material production	kg CO_2e/pouch of total	99.997%	99.998%	99.998%	Production: Germany
Sewing step	kg CO_2e/pouch	0.003%	0.002%	0.002%	Production: Germany
Total emissions	kg CO_2e/pouch	60%	74%	100%	

Table 49: Market-based scope 2 emissions of alternative 2 in worst case.

	Unit	S	M	L	Comment
VFFS machine	kg CO_2e/pouch of total	99.97%	99.97%	99.98%	Production: Germany
Sewing step	kg CO_2e/pouch	0.03%	0.03%	0.02%	Production: Germany
Total emissions	kg CO_2e/pouch	67%	67%	100%	

Table 50: Market-based scope 2 emissions of alternative 2 in best case.

	Unit	***S***	***M***	***L***	***Comment***
VFFS machine	kg CO_2e/pouch of total	99.94%	99.93%	99.95%	Production: Germany
Sewing step	kg CO_2e/pouch	0.06%	0.07%	0.05%	Production: Germany
Total emissions	kg CO_2e/pouch	66%	66%	100%	

A.3 Scope 3 emissions

Table 51: Ratio of CO_2-emissions per pouch per transportation process of the actual pouch.

Pouch type	***Ratio of CO_2-emissions per pouch per process***		
	Raw material (a)	*Semi-finished product (b)*	*Finished product (c)*
S light	39%	20%	40%
M light	39%	20%	41%
L light	36%	21%	42%
S normal	37%	24%	39%
M normal	39%	20%	40%
L normal	36%	21%	42%
Average	**38%**	**21%**	**41%**

Table 52: Ratio of CO_2-emissions per pouch per transportation process of the actual pouch.

Pouch type	***Ratio of CO_2-emissions per pouch per process***		
	Raw material (a)	*Semi-finished product (b)*	*Finished product (c)*
S light	35%	60%	4%
M light	31%	65%	5%
L light	38%	58%	4%
S normal	31%	65%	4%
M normal	35%	61%	4%
L normal	38%	58%	4%
Average	**35%**	**61%**	**4%**

Table 53: CO2-emissions of actual pouch relative to normal pouch in size S.

Pouch type	***CO_2-emissions relative to normal pouch in size S***			
	a	*b*	*c*	***Total***
S light	90%	73%	86%	**84%**
M light	113%	92%	110%	**107%**
L light	129%	117%	140%	**131%**
S normal	*100%*	*100%*	*100%*	***100%***
M normal	129%	105%	125%	**121%**
L normal	150%	137%	164%	**152%**

Table 54: CO2-emissions of alternative sourced pouch relative to actual pouch.

Pouch type	***CO_2-emissions relative to actual pouch***			
	a	*b*	*c*	***Total***
S light	96%	317%	12%	**107%**
M light	75%	304%	11%	**96%**
L light	128%	335%	12%	**123%**
S normal	96%	317%	12%	**115%**
M normal	94%	315%	12%	**106%**
L normal	128%	335%	12%	**123%**
Average	103%	320%	12%	**112%**

Table 55: Ratio of CO_2-emissions per transportation process for the raw material of alternative 2.

Step	***CO2-emissions [gCO2e/pouch]***			
	S	***M***	***L***	***Average***
a	75%	96%	129%	100%
b	21%	26%	26%	27%
c	7%	8%	11%	9%
d	17%	21%	28%	22%

A.4 Transportation modalities

Table 56: Tonne-kilometres per truckload and transportation process for the actual pouch.

Pouch size	***Raw material (a) (t-km)***	***Semi-finished product (b) (t-km)***	***Finished product (c) (t-km)***
S light	2,627	1,575	3,283
M light	2,627	1,603	3,342
L light	2,627	1,786	3,727
S normal	2,627	1,955	4,083
M normal	2,627	1,589	3,313
L normal	2,627	1,786	3,727

Pouch size	***Raw material (a) (t-km)***	***Semi-finished product (b) (t-km)***	***Finished product (c) (t-km)***
S light	2,564	5,050	392
M light	2,564	6,302	490
L light	2,564	4,555	353
S normal	2,564	6,276	408
M normal	2,564	5,217	405
L normal	2,564	4,545	352