Jesper van der Molen

Developing of Design Criteria Considering Sustainability Performance of Food Processing Equipment

While Investigating Sustainable Soluble Gas Stabilization Design Concepts

Master's thesis in Mechanical Engineering: MTPROD
Engineering Design and Materials
Supervisor: Assoc. Prof. Anna Olsen
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June 2023

Master's thesis

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PREFACE

This thesis represents the culmination of five years of study and one year of research conducted as part of a Master's degree program in Product Development at The Norwegian University of Science and Technology. Throughout this process, I had the privilege of exploring a topic that is of great interest to me and contributing to the existing body of knowledge in the food industry. I am grateful for the guidance, feedback, and support provided by my excellent supervisors, whose participation and cooperation were essential for the completion of this research.

I would also like to express my heartfelt gratitude to my family and friends for their unwavering love, support, and encouragement throughout my academic journey. Their presence has been a constant source of motivation for me.

This thesis is motivated by a strong belief that the majority of people from my generation share a solid desire and determination to work towards sustainability. The pressing issues of the environment and climate change surround us, making us acutely aware that the repercussions of neglecting our planet's well-being will primarily impact our generation and those to come. Witnessing the gravity of these consequences, it is heartening to observe a growing emphasis on environmental and sustainability issues, even on a global scale, as governments increasingly prioritize these concerns.

The world is confronted with a rapidly growing human population, and the demand for basic needs, including food, is on the rise. While efforts are made by individuals to reduce their environmental impact, true change requires governmental and collective action. As a product developer, I recognize the potential to not only meet needs, but also stimulate desires for sustainability. Companies, driven by market needs and influenced by people's values, have the power to shape the future. Therefore, it is essential to prioritize environmental considerations as a society, understanding the underlying reasons and embracing sustainability as a core value. We the people hold the responsibility and the power to drive meaningful change.

As I embark on the journey of exploring the concept of sustainability in depth for my master's thesis, I find myself deeply inspired by the profound insights shared by scholars, like John Ehrenfeld, describing sustainability as *"the possibility that humans and other life will flourish on Earth forever"* [1]. Such visions of sustainability as the perpetual flourishing of both humanity and all forms of life on Earth resonates with me on a profound level. It serves as a reminder that we are not only custodians of this planet but also responsible for its long-term well-being. It is evident that a transformation of both individual and collective human behaviors is needed. The pursuit for such a change resonated deeply with me and served as a catalyst for my commitment to defining the significance of sustainability and even effected sustainable changes in my own personal life. Drawing upon such sources, I have been motivated to further delve into the complexities of sustainability, and to contribute meaningfully to the discourse on creating a sustainable world. Through this thesis, I aspire to explore new avenues of understanding, generate innovative ideas, and inspire action towards a future where sustainability thrives, both individually and collectively.

In writing this thesis, I aspire to contribute to the ongoing discourse on sustainability, seeking to expand our understanding of its multifaceted nature and exploring practical avenues for fostering its implementation in the early design phase of industrial product development. By incorporating these inspiring ideas into my research and advocating for sustainable living, I hope to not only deepen my academic knowledge but also inspire the embracing of sustainability as an essential element in any product, industry or environment. May this thesis serve as a testament to the transformative power of sustainable thinking, encouraging dialogue and action that will shape a world where humans and nature can flourish together, now and for generations to come.

I hope this thesis contributes to the ongoing conversation in sustainability and inspires further research and practical implementation. May it serve as a reminder of our collective responsibility to work towards a sustainable future, where our values and actions align for the betterment of our planet and generations to come.

ABSTRACT

This master thesis focuses on the implementation of sustainability objectives in the design phase of industrial up-scaling for food processing technologies. The main objective is to develop guidelines for incorporating sustainability principles through the utilization of the United Nations' SDAG (Sustainable Development Analytical Grid) tool, which draws inspiration from sustainability-oriented innovation, design for environment, and Sustainability by Design. The study engages key stakeholders, particularly an FPE manufacturer, to assess the existing industry's sustainability performance, until finally primary and secondary design criteria are identified. Using a systems engineering approach influenced by set-based product development, the thesis explores the optimization of inlet and outlet configurations for a Soluble Gas Stabilization Food Processing Equipment (SGS FPE). A comprehensive set of design specifications, derived from the sustainable results of the SDAG tool and supplementary requirements, guides the evaluation and refinement of alternative SGS concept design solutions. The sustainability impact of the alternative design solutions are evaluated and can be compared, showcasing not only how to optimize a sustainable solution, but in general how to create, prioritize and utilize a specific list of sustainability guidelines. The guidelines aid in implementing all aspects of sustainability in the early design phase of new product development, while also exhibiting improvement area recommendations for industry stakeholders.

Through the research, the significance of sustainability is underscored, emphasizing its growing importance, although challenges remain in integrating it with other critical aspects such as continuity, efficiency, and costs, especially in industrial up-scaling. The thesis provides valuable insights, offering guidelines for integrating sustainability objectives in the design phase of industrialization of food processing technologies. It contributes to the broader discussion on sustainable design in the industry and sets the stage for future research and practical implementation, while also having started the concept development of a preliminary SGS equipment design.

Summary

This master thesis focuses on the implementation of sustainability objectives in the design phase of industrial up-scaling for food processing technologies. The study aims to develop guidelines for integrating sustainability principles using an SDAG tool, based on the UNs SDGs, and in this study also inspired by sustainability-oriented innovation, design for environment, and sustainability by design. The research involves assessing the sustainability performance of the industry and collaboratively establishing primary and secondary design criteria with key stakeholders, particularly an FPE manufacturer.

Using a systems engineering approach, the thesis investigates the optimization of inlet and outlet configurations for sustainable concept development of the Soluble Gas Stabilization (SGS) technology. A comprehensive set of design specifications, based on the results from the SDAG tool and other relevant requirements, guides the evaluation and optimization of alternative design solutions in the concept development phase. The sustainability impact of the final alternatives can then be assessed based on the industry's sustainability performance and the comprehensive set of design specifications.

The findings highlight areas for improvement in the implementation of sustainability in the food processing industry and the introduction of sustainable design criteria in the product development process for SGS process equipment. The research emphasizes the increasing importance and prioritization of sustainability in the food processing industry, but challenges remain in integrating sustainability in the design phase of newly developed products, especially in terms of continuity, efficiency, and cost considerations related to industrial up-scaling.

Through the master's thesis, there is target in addressing questions regarding how different sustainability principles are prioritized in the industry and how sustainability can be integrated into the design phase of newly developed products. Of particular interest is the examination of sustainability in the Norwegian salmon industry, considering the Norwegian government's introduction of salmon taxes and other constraints and challenges related to stakeholder involvement and achieving sustainability goals. The findings from the thesis can provide valuable recommendations for stakeholders to identify and improve sustainability performance in current and future processing equipment. Possibly, the findings are also transferable to other industries.

Sammendrag

Denne masteroppgaven fokuserer på implementeringen av bærekraftsmål i designfasen av oppskaleringen av industrielle matbehandlingsteknologier. Målet er å utvikle retningslinjer for integrering av bærekræftprinsipper ved hjelp av et SDAG-verktøy, som er et verktøy basert på FNs bærekraftsmål, og i denne oppgaven også inspirert av bærekraftsorientert innovasjon, produktutviklingsmetoden *Design for Miljø* og bærekraftig design. Forskningen involverer vurdering av bransjens nåværende bærekraftsytelse og samarbeider med sentrale interessenter, særlig en prosesseringsutstyrsleverandør, for å etablere primære og sekundære designkriterier.

Ved hjelp av en systemteknisk tilnærming utforsker oppgaven optimaliseringen av innløps- og utløpskonfigurasjoner for bærekraftig konseptutvikling av den nye teknologien *Soluble Gas Stabilization (SGS)* (løselig gasstabilisering). Et omfattende sett med designspesifikasjoner, basert på resultatene fra SDAG-verktøyet, men også andre relevante krav, veileder evalueringen og optimaliseringen av de alternative designløsningene som utvikles i konseptutviklingsfasen. Bærekraftseffekten av de endelige alternativene kan så vurderes videre ut fra bransjens bærekraftsytelse og det endelige, omfattende designspesifikasjonssettet.

Funnene fremhever forbedringsområder i implementering av bærekraft innen matbehandlingsindustrien og introduserer bærekraftige designkriterier i produktutviklingsprosessen for SGS-prosessutstyr. Forskningen understreker den økende betydningen og prioritering av bærekraft i matprosesseringsindustrien, men det gjenstår utfordringer med å integrere bærekraft i designfasen av nyutviklede produkter, da det fremdeles er et høyere fokus på kontinuitet, effektivitet og økonomi, spesielt når det kommer til oppskalering av industriell produksjon.

Masteroppgaven håper å gi svar på hvordan ulike bærekraftsprinsipper blir prioritert i industrien, og hvordan så bærekraft kan bli integrert i designfasen av nyutviklede produkter. Spesielt interessant er det å se på bærekraft i norsk lakseindustri med tanke på den norske stats innføring av lakseskatt, og generelle andre begrensninger og utfordringer i blant annet manglende interessentunvolvering og generelle vanskeligheter ved oppnåelse av bærekraftsmål. Funnene fra oppgaven kommer mest sannsynlig til å kunne brukes som anbefalinger for interessenter til å oppdage og forbedre bærekraftytelser i både næværende og fremtidig prosesseringsutstyr, og kan muligens også overføres til andre industrier.

Contents

List of Figures

ABBREVIATIONS

List of all abbreviations in alphabetic order:

- **ATP** Adenosine Triphosphate
- **Cefic** The European Chemical Industry Council
- **CO_2** Carbon Dioxide
- **DA** Data Analytics
- **DF** Degree of Filling
- **DfE** Design for Environment
- **DfX** Design for X
- **DNA** Deoxyribonucleic Acid
- **DOE** Design of Experiments
- **DSM** Design Structure Matrix
- **DTM** Design Theory and Methodology
- **EFFoST** European Federation of Food Science and Technology
- **EHEDG** European Hygienic Engineering and Design Group
- **EU** European Union
- **FAO** Food and Agriculture Organization
- **FCR** Food Conversion Ratio
- **FDA** Food and Drug Administration
- **FPE** Food Processing Equipment
- **FTIR** Fourier Transform Infrared
- **GHG** Greenhouse Gas
- **HACCP** Hazard Analysis Critical Control Point

- **HLPF** High-Level Political Forum
- **HPP** High-Pressure Processing
- **HSE** Health, Safety and Environment
- **HSI** Hyperspectral Imaging
- **IoT** Internet of Things
- **ISO** International Organization for Standardization
- **LCA** Life Cycle Assessment
- **LPD** Lean Product Development
- **MAP** Modified Atmosphere Packaging
- **MCDM** Multiple-Criteria Decision Making
- **NOK** Norwegian Kroner
- **NASA** National Aeronautics and Space Administration
- **NAV** Norwegian Labor and Welfare Administration
- **NPD** New Product Development
- **NTNU** Norwegian University of Science and Technology
- **PEF** Pulsed Electric Field
- **pH** Potential of Hydrogen
- **PSPP** Policies, Strategies, Programs and Projects
- **PU** Polyurethane
- **PVC** Polyvinyl Chloride
- **R&D** Research and Development
- **SAE** Society of Automotive Engineers
- **SBCE** Set-Based Concurrent Engineering
- **SBD** Set-Based Design
- **SDAG** Sustainable Development Analytical Grid
- **SDG** Sustainable Development Goal
- **SDI** Sustainability-Driven Innovation
- **SE** Systems Engineering
- **SGS** Soluble Gas Stabilization

- **SII** Sustainability-Informed Innovation
- **SOI** Sustainability-Oriented Innovation
- **SRI** Sustainability-Relevant Innovation
- **UIA** International Union of Architects
- **UN** United Nations
- **UNESCO** United Nations Educational, Scientific and Cultural Organization
- **USDA** United States Department of Agriculture
- **UV** Ultraviolet
- **WHC** Water-Holding Capacity

CHAPTER

ONE

INTRODUCTION

Food security and safety, as well as sustainable food production, have become increasingly important in European politics and global initiatives, such as the Sustainable Development Goals (SDGs) and Agenda 2030 by the United Nations (UN). In order to meet these goals, it is necessary for the food industry to improve their processing and production technologies while considering sustainability issues. However, designing novel industrial equipment that takes sustainability into account is a complex and challenging task that requires a holistic approach. Such a holistic approach is suggested, as a combination of systems engineering, some set-based design practices, and sustainability by design; all in all providing a structured approach for designing and improving complex systems in a sustainable way. Through contact with industry stakeholders and investigation of the current sustainability performance of existing food processing equipment, the findings can be used to improve the sustainability performance of future food processing equipment and work as general sustainability implementation guidelines.

1.1 Motivation

Despite the increasing importance of sustainable food production and the role of food processing in achieving this goal, designing equipment that is both sustainable and effective remains a significant challenge. While sustainability standards and guidelines exist, they often lack specificity and do not provide clear instructions for implementation. Furthermore, sustainability considerations are often given low priority in the design process due to factors such as cost and performance.

The food industry contributes significantly to global environmental challenges, such as greenhouse gas emissions, water usage, and waste generation. With the growing population, there is a need to increase food production. To tackle these issues, developing sustainable and efficient food processing equipment is crucial.

This master thesis aims to contribute to the development of sustainable food processing equipment by applying the systems engineering methodology to the design process. The methodology offers a structured approach to designing and improving complex systems while taking into account sustainability considerations. By investigating the sustainability performance of existing equipment and using these findings to inform the design of future equipment, the research aims to improve the sustainability performance of food processing equipment and contribute to the broader goal of sustainable food production, creating sustainable design specifications.

To showcase these sustainable design specifications, the study works on a specific food processing equipment that is yet to be produced commercially. It's technology has the potential to be little sustainable and environmentally unfriendly, therefor creating a complicated situation for it's concept development. Which parts of sustainability are evaluated to be the most important for different stakeholders? Can the social sustainability be forgotten as long as the economic sustainability is great? Does a high energy consumption really matter if the processing equipment extends the shelf life of its products?

Overall, the research seeks to address the challenge of designing sustainable food processing equipment by applying a structured methodology that prioritizes sustainability considerations. The results of this research have the potential to contribute to the development of more environmentally friendly food processing practices, thereby contributing to the broader goal of sustainable food production.

1.2 Main Objectives and Scope

The main objective of the master's thesis is to investigate the development and optimization of the inlet and outlet components of inline soluble gas stabilization technology for sustainable salmon processing. The study will explore different designs of the entire processing technology, attempting to assess both their impacts on the shelf life of the processed salmon and their sustainability impacts. The thesis will evaluate the environmental feasibility of the proposed designs based on relevant stakeholders' evaluations of sustainability parameters in the food processing industry, and integrate these evaluations in the design process. Keep in mind that the thesis is a continuation of an in-depth study, where a list of sustainable design criteria according to *one* stakeholder are already identified. The findings of the thesis will contribute to the development of a sustainable basis for future food processing technologies and provide guidance for future research and implementation of this technology. The efforts made to reach the main objective are separated into the following exercises:

- Continue the work of the in-depth-study [2] and evaluate all aspects of sustainability of an existing food processing equipment using the *Sustainable Development Analytical Grid* (SDAG) in collaboration with industry stakeholders.

- Further develop and use a concrete list of design criteria for developing preliminary sustainable design concepts of full-scale *Soluble Gas Stabilization* (SGS) technology.

- Develop and optimize inlet and outlet configurations to ensure sustainability within the processing system using a systems engineering approach.

- Evaluate the proposed equipment designs in terms of sustainability impacts as well as the quality of the processed salmon, providing possible stand-out solutions, while creating a guide for sustainability implementation in concept development.

1.3 Research Question

The research question the thesis aims to answer is the following:

> How to prioritize the significance of sustainability to be integrated into the design phase of the industrial up-scaling of food processing technologies.

Initially, the study aims to define new design criteria that contribute to developing a preliminary design for a sustainable concept of full-scale Soluble Gas Stabilization (SGS) technology. Consequently, the design criteria, as part of design specifications, can act as guidelines in how to generally implement new technologies in a production line in the most sustainable way possible.

1.4 Expected Outcomes

Some of the expected outcomes include:

1. A detailed understanding of the sustainability performance of existing food processing equipment, based on a comprehensive investigation of sustainability criteria and standards.
2. Identified key areas where the sustainability performance of food processing equipment can be improved, based on the findings of the investigation.
3. Development of new design concepts and prototypes for the Soluble Gas Stabilization food processing equipment, that incorporates sustainability criteria and standards.
4. Recommendations for industry stakeholders on how to improve the sustainability performance of food processing equipment in the future, based on the findings of the research.

Overall, the expected outcomes of the master thesis are to contribute to the development of sustainable food processing practices and equipment by providing a structured methodology and design approach that prioritized sustainability considerations. By identifying areas for improvement and developing new design concepts and prototypes, the research has the potential to contribute to the broader goal of sustainable food production while addressing a critical challenge facing the food industry.

1.5 Approach and Constraints

It is important to acknowledge certain limitations that may impact the scope of the research. Firstly, the availability and engagement of industry stakeholders in the evaluation and collaboration process may be subject to their availability and willingness to participate, potentially influencing the depth of stakeholder engagement, as was mentioned in the in-depth study. When it comes to this, the time and resource constraint must also be considered, as the available timeframe for conducting the research and completing the thesis may impose limitations on the depth and breadth of the investigation. Additionally, other project limitations include the current political discussion within the geographic scope of Norway, as well as limitations of the research focus on sustainability and SDGs. These limitations will be taken into account throughout the study to ensure a comprehensive yet feasible examination of the proposed technology and its sustainability impacts. Many of the limitations identified in the preceding in-depth study remain unchanged in the research. However, some of the limitations introduced then are not as decisive and extensive as before.

1.5.1 Contact with the Industry

One significant limitation relates to the contacts with industry stakeholders. The in-depth study highlighted the preference for analyzing the SDAG tool with a group of analysts that includes all relevant stakeholders, fostering discussions until a consensus is reached. However, due to the study's duration and limited access to industry contacts, achieving this scenario is practically impossible. Moreover, as an external researcher engaging with companies, it is challenging to gather multiple dedicated stakeholders willing to invest their time and effort in discussions within an already busy work environment. Consequently, the initial in-depth study only managed to interview a single company stakeholder; a processor. The thesis includes the results from the processor, but has yet again only managed to include participation from one other added stakeholder; an FPE manufacturer.

For this to be further avoided, a more thorough stakeholder analysis could have been performed in the in-depth study. In this case, the stakeholder analysis was primarily used for the purpose of identifying the most relevant stakeholders to engage in communication. Nevertheless, it remains crucial to have conducted a certain level of stakeholder analysis in order to identify their diverse perceptions, definitions, and approaches to capturing value. Stakeholder management is considered critical for developing sustainable products, and the benefits of the analysis include identifying the interests, attitudes, risks and influences of all stakeholders [3]. As can be seen in Figure 1.5.1, a power-interest grid helps identify the involvement prioritization of the relevant stakeholders, and would help initially recognize which stakeholders need more prioritization, involvement and decisive power. However, one could argue that the relatively short duration of the study does not necessitate an extensive stakeholder analysis, as the stakeholders were primarily only involved in the objective evaluation process for defining criteria. A more in-depth analysis would be particularly crucial in a more advanced stage of a concrete design process. Generally, the limitations in different stakeholders involvements roots in the short duration of the research time.

Through the expanded participation with one extra stakeholder, it has become evident that there are some significant differences in objective prioritization between the two stakeholders. This underscores the existence of information gaps and suggests that the assessment would have been better conducted in a multi-stakeholder meeting, including governmental stakeholders as well.

That being said, both the manufacturer and the processor make up some of the most important stakeholders of the overall research, being part of food industry. Therefor, their knowledge and consequent results in the assessment tool can represent not only their own areas of expertise, but also some others. While the

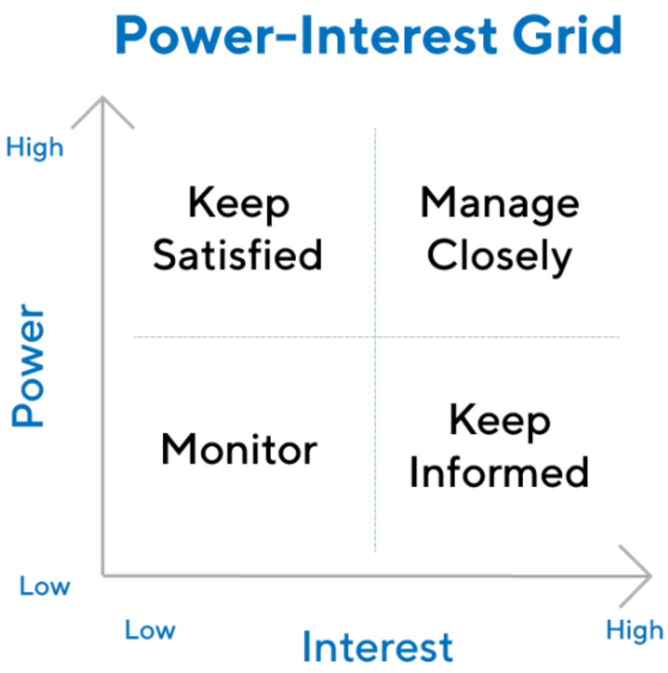

Figure 1.5.1: A power interest grid can help keep keep stakeholders engaged. It can be argued that the manufacturer is more close, if not within, the "manage closely" relative to the processor, who is more within the "kept satisfied" sector

SDAG tool has not separately assessed objectives with e.g. governmental stakeholders, consumers or factory employees, much of the information provided by the manufacturer and processor indicate what the other stakeholders views are. For instance, the manufacturer recognizes that many objectives are client-dependant. While optimally, all stakeholders should be independently represented, it can be claimed the tool results already constitute multiple stakeholders views *to some degree*. A more thorough discussion on this is added in section 2.4

1.5.2 Governmental Introduction of Resource Rent Tax on Aquaculture

During the in-depth study period, the Norwegian Government implemented a new "salmon tax," (September 2022), which had a significant impact on the research. This development limited the opportunities for conducting additional employee interviews and company visits. The government's rationale for introducing this tax was to ensure that society receives a fair share of the extraordinary returns generated from the exploitation of aquaculture resources, with an estimated resource rent of NOK 11.8 billion in 2021 [4].

Although the new resource rent tax was not to come into effect until 2023, it already caused radical changes within the salmonid food industry the year before. As a result, numerous workers were facing the immediate risk of job losses, as evidenced by the substantial number of layoff notices issued by major companies such as Salmar and Lerøy [5] [6]. These significant changes and uncertainties somewhat diminished companies' interest in participating in studies like the present one. However, they also heightened awareness of the social dynamics within the industry. The context of the governmental resource rent tax on aquaculture has created both challenges and opportunities for the research. On the one hand, companies' decreased willingness to participate has posed limitations on data collection. On the other hand, it has brought increased attention to the social aspects of company operations, prompting a greater focus on the social environments in which they operate.

Even though the controversial tax was initially implemented from January 1st 2023, the exact details of how the government intended it to be structured were only made known just before Easter. The aquaculture industry has strongly opposed the introduction of the resource rent tax on aquaculture since the announcement was made. The new resource rent tax introduced by the Norwegian government demanded that all Norwegian companies that produce salmon, trout and rainbow trout should pay 40 per cent in tax, which initially was estimated to provide up to NOK 3.8 billion in income (from fish farming and wind power) [4]. However, recently the Ministry of Finance released calculations that indicated it could be much larger, potentially reaching up to NOK 17 billion this year. The resource rent tax primarily impacts large companies, while providing a protective shield for small ones, which may potentially influence production. Professor Torfinn Harding, an economist at the University of Stavanger Business School, has proposed various additional effects of the resource rent tax. These effects include the potential abandonment of new investments and an increased instability and unpredictability, leading to reduced trust among stakeholders [7].

As was discussed in the in-depth study; nevertheless, there has been a debate regarding the extent to which this tax truly affects companies. A report by DN [8] highlights that in 2021, approximately 2,700 employees in the Norwegian salmon industry received layoff notices due to seasonal variations. This number is not significantly lower than the layoffs in 2022. This suggests that an individual may receive multiple notices and that a notice does not necessarily result in an actual layoff. Moreover, data from the Norwegian Labor and Welfare Administration (NAV) requested by DN [8] indicates that 2,300 permission notices were already issued in 2022 before the introduction of the resource rent tax. This implies that the tax is unlikely to be the primary cause for the high number of permissions. Thus, the extent to which the resource rent tax truly impacts the number of layoff notices remains unclear. However, there are valid reasons to believe that the tax introduction will affect production and processing to some degree. Furthermore, the frequency of permissions, influenced by governmental constraints, as well as seasonal, resource, and market variations, suggests that job security is not guaranteed.

At the moment of writing, there are still many political discussions on the resource rent tax, how large it should be, and it's significance, with several political parties choosing to no longer participate in the negotiations [9]. In May 2023, the provisional tax was also lowered from 40% to 35% and finally to 25% before an agreement was made [10]. The final decision was passed by the Norwegian Parliament (the Storting) on the 31. of May [11]. Therefor, currently, apart from stock market changes, the long-term consequences of the salmon tax remain somewhat unknown. It is also expected that there will be changes to the taxing system, especially in the case of a change of government [12]. However, three days after the official governmental decision on the resource rent tax, MOWI, the world's largest

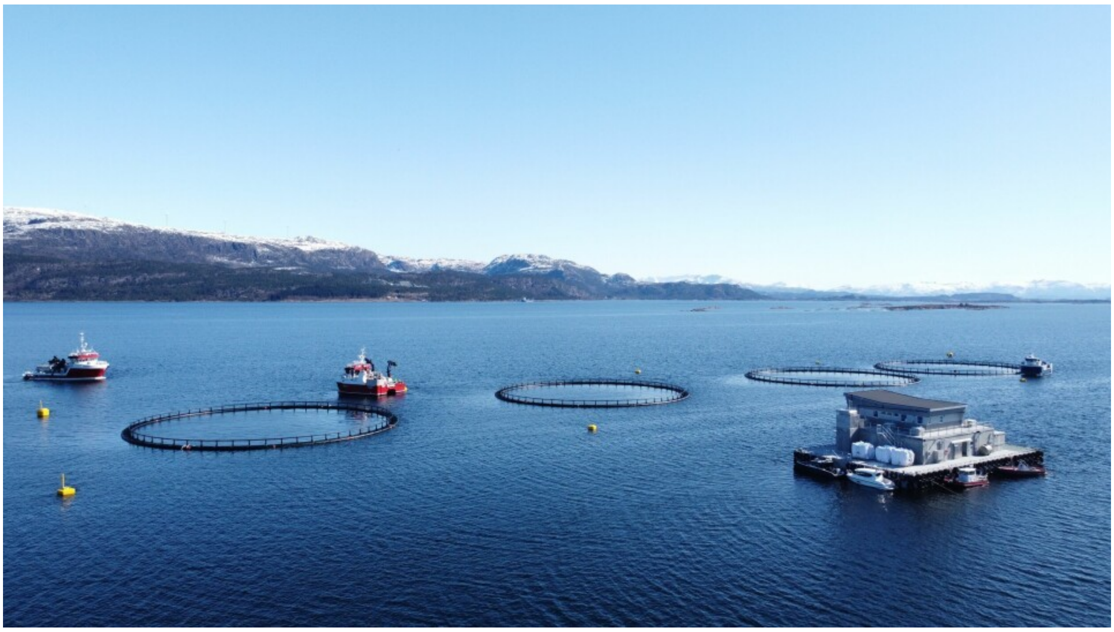

Figure 1.5.2: An example of a Salmon Fish Farm in Norway.
A resource rent tax on fish farming can be profitable for smaller Norwegian municipalities, while costly for others. (Photo: Marius Strømmen/Godfisken)

salmon farmer company, stated that they are dropping a planned investment of NOK 5 billion as a direct consequence of the tax [13]. This cut in investments is estimated to effect up to 1400 man-years. According to CEO Ivan Vindheim: *"This cut is only the beginning, as the tax will effect all investment evaluations"* [14]. At the same time, Mowi have also used the resource rent tax as an argument for investing and establishing salmon farms in smaller municipalities, as the host municipalities are guaranteed a higher income from the Aquaculture Fund for 2023 [15]. The distribution of the resource rent tax ensures that 45 percent goes to the state, and 55 percent goes to host municipalities and counties, which can make it attractive for smaller low tax income municipalities to provide areas for fish farms. It remains clear that the salmon tax will most probably have a long term effect on the future investment, as was suggested by Torfinn Harding. Discussions and uncertainties have created less safety of jobs and economic viability, therefor also effecting some of the most important aspects of this specific study. The governmental constraints are important to consider in conceptual design, and can clearly impact the other stakeholders.

1.5.3 Short Term Problem Prioritizing

In contemporary business environments, the prevailing tendency among industries is to prioritize short-term issues over long-term sustainability concerns. While it is widely recognized that sustainability is a long-term challenge, the pressures faced by CEOs to maintain immediate organizational strength often overshadow the drive for long-term objectives. This phenomenon, commonly referred to as short-termism, poses a significant obstacle in addressing the threat of climate change and thereby restricts the scope of the study.

The climate crisis can be likened to the American financial crisis of 2008, as stated by Paulson [16], where the collision of short-term thinking and long-term consequences is evident for both businesses and governments. To effectively confront the challenges posed by climate change, it is imperative to assess risks promptly. Although companies may invest in adapting to the current climate conditions, the decisions made today can inadvertently lock them into long-term consequences that necessitate far greater adaptation costs in the future. The correlation between short-termism and the threat of climate change serves as a limiting factor in this study's context.

A report from the Capgemini Research Institute highlights the persistent disparity between long-term ambitions and short-term concrete actions, despite organizations acknowledging the importance of sustainability and making commitments to achieve net-zero goals [17]. Sustainability is often perceived as a cost center rather than a value center, particularly within the global macroeconomic landscape. The report further reveals that the main drivers for sustainability initiatives are pressures from current and future employees (cited by 60% of executives) and the need to proactively anticipate stricter future regulations (cited by 57% of executives). Additionally, 52% of executives expect sustainability efforts to increase future revenue [17]. However, many businesses hesitate to take action due to concerns about short-term cost implications. Consequently, there is a crucial need for companies to align their short-term objectives with a clear strategy that delivers concrete outcomes, enabling society to exist within planetary sustainable boundaries.

The prevalent emphasis on short-term problem prioritization poses a significant challenge in addressing sustainability issues effectively. The clash between short-term thinking and long-term consequences, exemplified by the climate crisis, highlights the urgency to assess risks promptly. Furthermore, the gap between long-term ambitions and short-term actions underscores the need for businesses to align their objectives and strategies to achieve sustainable outcomes. By overcoming short-termism and adopting a holistic approach that integrates both short-term and long-term perspectives, companies can play a crucial role in shaping a sustainable future.

1.5.4 General Issues of SDGs

In general, the Sustainable Development Goals aim to address issues such as world hunger, extreme poverty, inequality, climate change, marine life, and clean energy. However, despite their positive intentions, certain problems have been discussed regarding the SDGs, as highlighted during the 2018 High-Level Political Forum (HLPF), an annual conference dedicated to reviewing SDG progress [18].

Xiao [18] outlines several general issues associated with the SDGs. One recurring concern is that the SDGs are voluntary commitments, meaning that countries may not follow through on their promises or face consequences for non-compliance. Additionally, corruption poses a significant obstacle, particularly in poorer countries where SDGs are most crucial. There is no assurance that the funds allocated to these countries for SDG implementation are being managed equitably. Similarly, even highly developed countries engage in practices such as tax evasion and offshore accounts that divert financial resources. Furthermore, the lack of comprehensive data makes it difficult to assess the effectiveness of the SDGs, as not all countries have dedicated monitoring departments to document SDG achievements. In order to achieve SDGs, there are many challenges in investments, having coordinated partnerships, effective leaderships, and general implementation [19].

To some extent, these general issues pertaining to the SDGs can also apply to companies' implementation of the results obtained from the devised Sustainable Development Assessment Grid (SDAG). While the tool aids companies in identifying areas for sustainability improvement, there is no guarantee that these areas will be prioritized since compliance remains voluntary. Furthermore, it is uncertain whether all companies effectively monitor their sustainability achievements or exhibit responsible financial management practices.

1.6 Structure

The thesis is structured as follows:

1. **Chapter 1** is the current introducing chapter, aiming to detail the motivation, scope, objectives and limitations of the study.

2. **Chapter 2** provides an overview of SGS technology, including soluble gas stabilization, the link between FPEs and sustainability, and salmonid processing. This chapter aims to describe the essentials of the Soluble Gas Stabilization technology, as well as present the reasons to why there is a sustainability focus in Norwegian salmonid processing, specifically in food processing equipment design.

3. **Chapter 3** details the product development process, including engineering design, set-based concurrent systems engineering, and sustainability-added design. This is included as part of the thesis to understand how the concept development process has taken form, and the reasoning to why it is done in this exact way. It aims to show both where the product development methods draw inspiration from, but also attempts to introduce the substances that comprise the SDAG tool. It details what needs to be considered before embarking on new product development (NPD), especially when including aspects of sustainability as specific design criteria, and how to prioritize these.

4. **Chapter 4** covers the identification and selection of product requirements, utilization of concept development, and defining the sustainable design criteria based on the use of an assessment tool in collaboration with a processor and a manufacturer - as well as other relevant parameters, until a final list of requirements ultimately helps in proposing solution alternatives. In this chapter, detailed information on sustainable design criteria is included, and implemented in the overall design specifications. At the same time, the concept development process is shown from early draft design. Some of the most important parameters, sustainable or not, are also investigated further to have the list of requirements as comprehensive as possible.

5. **Chapter 5** showcases the design solution alternatives of SGS in detail and presents the list of design specification with the requirements now prioritized in order of implementation importance.

6. **Chapter 6** offers a discussion of the solution alternatives relative to the defined requirements, conclusively offering a short comparison of them - in a search for optimization. It also highlights the current state of the project using some of the product development methods introduced in Chapter 3.

7. **Chapter 7** Concludes the thesis with a summary of the main findings and suggestions for future work within the related subjects.

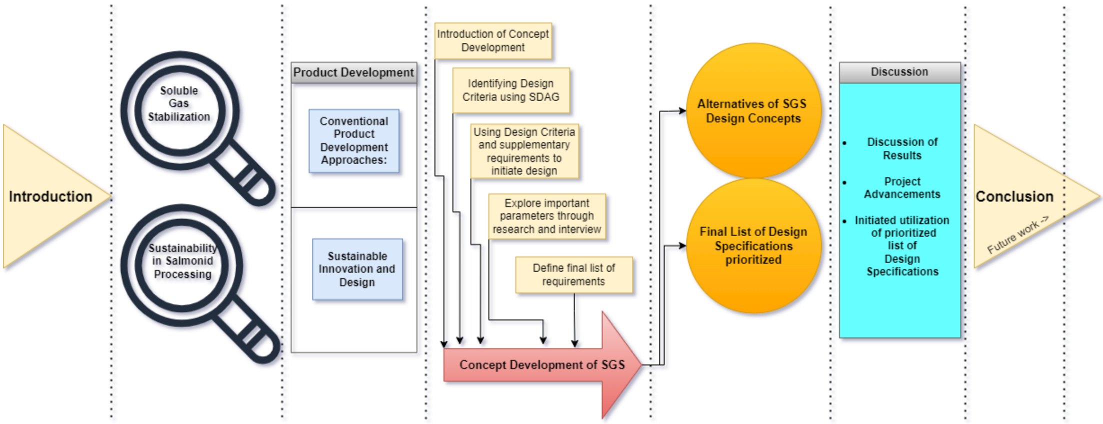

Figure 1.6.1: The structure of the study.

CHAPTER

TWO

SGS TECHNOLOGY AND SUSTAINABLE SALMONID PROCESSING

2.1 Soluble Gas Stabilization

Food industries are continuously seeking new technologies to extend the shelf life of products while maintaining nutritional quality and safety. Different thermal and nonthermal processing methods have been developed to achieve microbial inactivation, but each method has its limitations and can reduce product freshness and sensory quality to some extent [20]. The demand for minimally processed foods is rising, making it necessary to find methods that preserve food quality and safety without causing adverse effects [21]. Combining existing and novel preservation techniques in a so-called "hurdle technology" is a promising approach to achieving maximal microbial lethality while also minimizing the damage to sensory and nutritional quality.

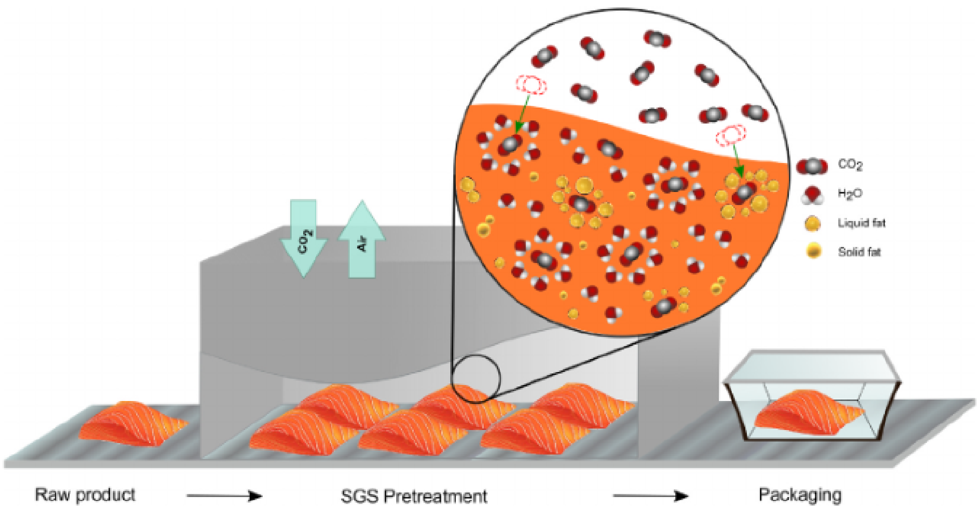

Figure 2.1.1: SGS pretreatment procedure.
Illustration of the SGS pretreatment procedure and dissolution of CO_2 into the liquid phase. For the SGS pretreatment, the atmosphere inside the chamber is evacuated and instead filled with almost 100% food-grade CO_2. [22]

Soluble gas stabilization (SGS) is a novel preservation technology that relies on the bacteriostatic effect of dissolved carbon dioxide (CO_2) to limit microbial growth and other deteriorating mechanisms in food products. It was first introduced by Sivertsvik [23]. SGS is considered a pre-packaging step, meaning that CO_2 is dissolved into the product *before* packaging [24] as shown in Figure 2.1.1. The bacteriostatic effect of CO_2 is proportional to the concentration of dissolved CO_2 in the food matrix [25].

Implementing SGS technology has demonstrated the ability to enhance the shelf life of food products by reducing microbial growth while maintaining taste and visual appeal over an extended period [26] [27] [28]. Additionally, SGS technology improves modified atmosphere packaging by enabling a higher degree of filling (DF), allowing for smaller packages [29]. See Figure 2.1.2. Modified atmosphere (MA) storage has been found to be advantageous for enhancing the shelf life of fresh and processed food in retail packages. See a model of MAP in Figure 2.1.2. The efficacy of MA packaging (MAP) relies on the amount of carbon dioxide (CO_2) available for dissolving into the food, which is determined by the gas's partial pressure inside the package and the degree of filling or the volume of the product in comparison to the package's volume. To ensure a sufficient employed SGS process, CO_2 is dissolved into the product, and the product spend at least two hours in pure CO_2 before retail packaging. SGS has the ability to prevent package collapse even at higher degrees of filling (e.g. 50%) without compromising the quality of the packaged food [27]. Consequently, SGS leads to more appropriately packaged products and an increased packaging efficiency [30].

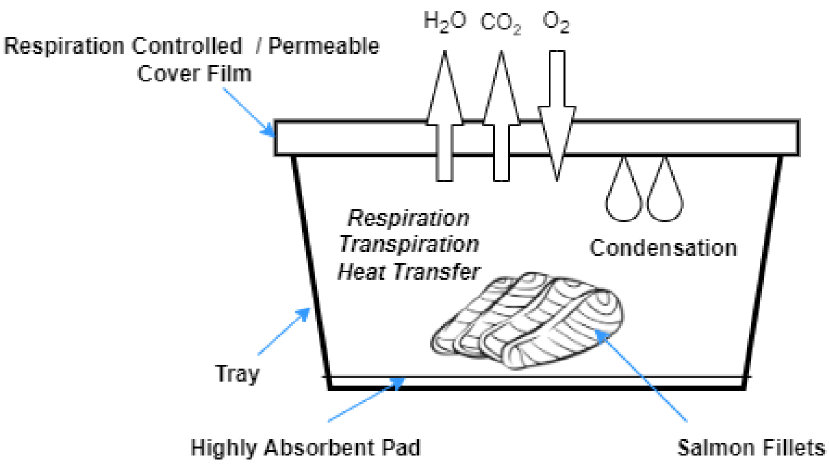

Figure 2.1.2: Modified Atmosphere Packaging (MAP).

In "The use of soluble gas stabilization technology on food – A review" by Esmaeilian et al. [22], the effect of SGS and dissolved CO_2 on food quality and shelf life was checked in the form of texture, color, drip loss, lipid oxidation, ATP degradation and microbiological load and composition. Particularly, the impact of modified atmosphere packaging (MAP) with superatmospheric CO_2 (SGS) on food quality and shelf life is a complex issue influenced by all those factors. Not all conclusions drawn in the review article are definitive or universally applicable, as there are diverse ranges of products, treatment methods, experimental protocols, compositions and product microbiota concentrations.

However, even though the effects of SGS and dissolved CO_2 on food quality and shelf life are multifaceted and influenced by numerous factors, which all need to be considered when evaluating its effects on specific food products, there are some common denominators. Some of the findings on the impact of SGS and CO_2 treatment from the review article include:

- SGS may reduce firmness in fish muscle and pre-cooked chicken breast due to pH reduction caused by CO_2 dissolution, thereby potentially leading to a significant loss of water-holding capacity (WHC) and succulence. However, the effect on **texture** can vary, and pH changes may not reach the muscle's interior.
- High CO_2 concentration in MAP can cause darkening in meat products, especially red meat. However, the impact on **color** depends on the product type and packaging conditions.
- **Drip loss** can increase with higher CO_2 concentration, but SGS treatment can help reduce it by dissolving CO_2 in the product before packaging. Microbial quality and WHC can also play a role in drip loss.
- CO_2 can influence **lipid oxidation** through pH reduction and oxygen levels. SGS may reduce lipid oxidation by limiting oxygen accessibility to the product.
- SGS and CO_2 can affect **ATP degradation** in food products, reducing the accumulation of undesirable compounds and enhancing desirable tastes. However, the effect may again vary depending on the product, and the mechanisms involved are still not fully understood.
- SGS and MAP can impact the **microbiota** of food products, with CO_2 inhibiting certain spoilage bacteria and influencing Gram-negative bacteria more than Gram-positive bacteria. The mechanisms involve changes in pH, membrane composition, and enzyme function.

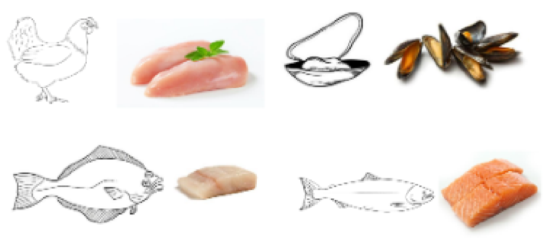

Figure 2.1.3: SGS impacts have proven to be product-dependant:
Laboratory trials have been performed on various types of muscle food [30].

Furthermore in the review article, the SGS method was checked in combination with thermal technologies (sous vide, microwave pasteurization, conventional pasteurization, ultra-high temperature, high temperature-short time) and non-thermal technologies (high-pressure, ultrasound, additives), and an overview of advantages and disadvantages on different foods is provided. A summary of this is not included in the thesis, as it has no significance for the beginning of the concept development. However, if there is potential of combining the SGS equipment with another processing treatment, a deep-dive into the effects of combining multiple processing methods should be embraced and researched further.

2.2 FPE and Sustainability

The development of food processing equipment (FPE) and processing technologies in general, presents an opportunity for reducing sustainability impacts, with the design step serving as a critical leverage point. Lindahl [31] highlights that the concept of sustainability is largely locked into the design step of product development, as this is where the lowest modification costs occur, and consequently, is the step with the most freedom of action in achieving sustainable outcomes. In 2015, Bar [32] demonstrated that by optimizing and redesigning FPEs to prioritize higher main product yields and minimize losses and discards caused by mechanical malfunctions or inaccuracies, substantial reductions in environmental impacts within the salmon supply chain could be achieved. Likewise, several other examples demonstrate that sustainability can be improved through the optimization or redesign of processing equipment; among others, Hansen et al. [33] presents examples of a hake filleting plant that reduces water consumption by one-third, and a herring filleting plant with significant lower organic wastewater content.

These findings suggest that caution and consideration of sustainability issues in the design process can help achieve sustainable development goals. However, to comprehensively address all sustainability aspects and maximize improvement opportunities in the design of new FPEs, an appropriate tool is needed.

A tool that can aid in the sustainability assessment of food processing equipment can be developed using the Sustainable Development Analytical Grid (SDAG), which is part of the United Nations' (UN) Sustainable Development Goals' (SDGs) Acceleration toolkit. The SDAG tool and its related processes was originally presented by Villeneuve et al. [34], and has been developed and tested on Policies, Strategies, Programs and Projects (PSPP) at local and national levels from 1988 onwards.

Figure 2.2.1: SDGs.
The Sustainable Development goals (SDGs) issued by the United Nations [35]

Furthermore, a specially devised SDAG tool can facilitate the establishment of sustainability objectives, identification of indicators, and informed decision-making, which can aid in the identification of trade-offs and new research questions towards a more sustainable FPE design. In contrast to many traditional design procedures that overlook social impacts, the SDAG assesses multiple dimensions of sustainability and remains scientifically robust and efficient. In their article

"A Systematic Tool to Consider Sustainability Issues in the Design Step Towards a More Sustainable Food Processing Equipment," Esmaeilian [36] conducted a comprehensive literature review on sustainability issues in relation to FPE to develop a sustainability assessment tool specially applicable for FPEs. As part of this thesis, the tool will be employed to identify improvement areas for more sustainable FPE design. As mentioned, this has already been done in collaboration with a stakeholder from a fish processing factory in the in-depth study [2], and will also be done in collaboration with an FPE manufacturer.

Figure 2.2.2 shows the flowchart of how the work will be done in order to reach a preliminary design. As can be seen from the figure, the black, numbered dots represent stakeholders in the product development that either provide constraints or have other impacts on the design specification. The main focus of the thesis is within the marked area, with the ultimate goal of working simultaneously with research institutes for a concept development with design specifications that together will work as a preliminary design. While employees, food industries, food suppliers, consumers and environment together lead to design criteria, the government and manufacturers create constraints (or enablers) before the design criteria can turn into design specifications. In subsection 1.5.2,a governmental constraint has already been introduced in the form of a salmon tax, possibly affecting the investment possibilities in many processing facilities' R&D departments. Keep in mind that the design criteria from the in-depth study already represent some of the stakeholders from this flowchart. Although the manufacturers are explicitly mentioned as constraint providers alongside the government, they are also considered part of the "food industries" stakeholder, thereby influencing the design criteria. Consequently, the thesis aims to compel manufacturers to contribute design criteria and provide supplementary information regarding constraints, enablers or additional considerations.

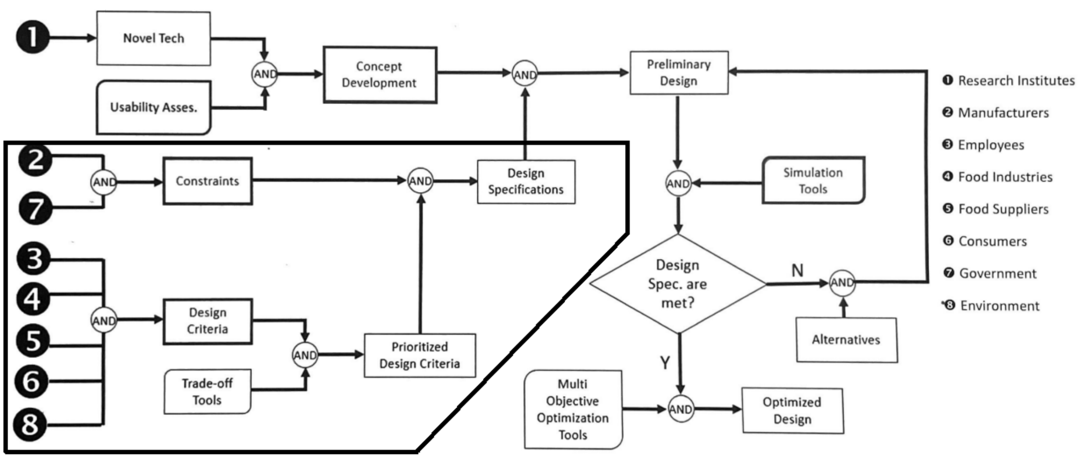

Figure 2.2.2: A work-flowchart for creating sustainable preliminary FPE designs. The marked area shows the main focus of this study. The flowchart was initially presented at the 35th EFFoST International Conference in Healthy Individuals, Resilient on November 2021, [37]. A zoomed in version of the flowchart is added later in Figure 4.3.13.

2.3 Salmonid Processing

To create guidelines on how to implement sustainability in the design phase of new product development, it has to be done in an area where such sustainability objectives are possible to envisage. In the study, those reached guidelines are implemented in the design phase of the SGS concept: a food processing technology. Food processing serves as great example of an area where multiple aspects of sustainability play big roles, specifically salmonid processing.

2.3.1 Why Focus on Seafood?

Fish processing refers to the various operations carried out on harvested fish, including grading, trimming, and filleting, as mentioned by Marel [38]. The primary objectives of processing are to preserve the fish and to enhance its economic and environmental worth by augmenting the value of the initial raw material, as highlighted by Fet, Schau, and Haskins [39]. The processing plants are facilities in which a range of procedures are done before preparing both wild-caught and farmed seafood for retail and consumption. While Figure 2.3.1 shows the supply chain *before* the fish processing plant, Figure 5.2.1 shows a complete outline of fish food processing. Seafood generally consist of highly perishable products, making plants necessary in order to preserve them with special care. As the term seafood involves a large variety of species, there is no uniform processing procedure, but there is a general flow, shown in Figure 5.2.1. Additionally, the main goal, independent of the product, consistently remains to preserve the shelf life.

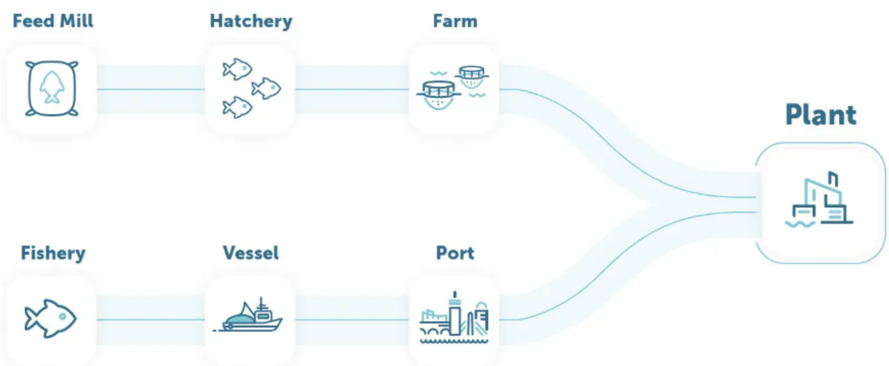

Figure 2.3.1: The Seafood Supply Chain before the processing plant. Source: Global Seafood Alliance [40]

Following the initial sorting and grading at the processing plant, the fish undergo two main routes. They are either gutted and frozen for shipment to the market or matured and transformed into fillets, resulting in multiple products and bi-products that are packaged separately before being sent to the market. It is important to note that the study does not cover another processing method specifically used for salmonid fish, known as pre-rigor processing. The pre-rigor processing method is primarily employed for premium fish products and involves more manual labor at higher skill levels due to the mechanical difficulties posed by the strong protein bonds present in fresh fish flesh, rendering automated handling impractical, as stated by Digre et al. [41].

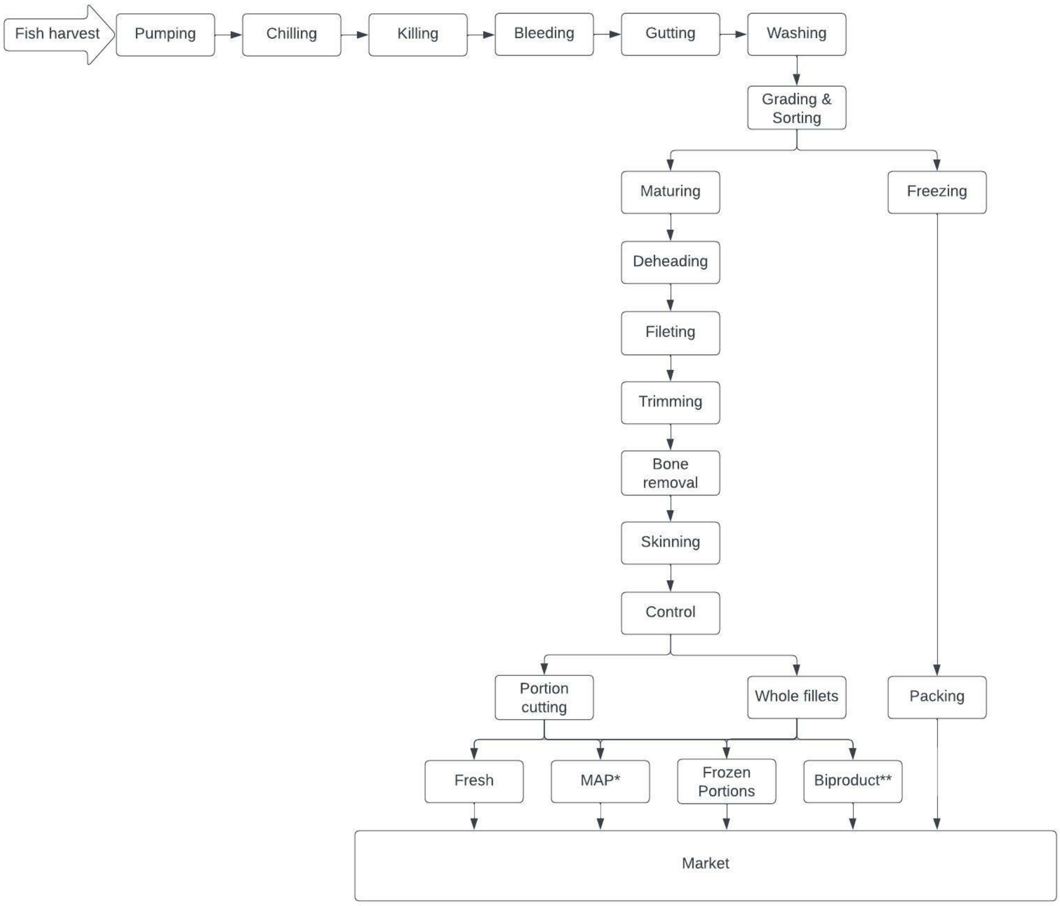

Figure 2.3.2: Overview of fish processing.
*MAP= Modified atmosphere packaging (often vacuum).
**Biproducts include skin, backbones, fars, silage, heads, scrape meat, brown meat, bellytrims and cuts. These are often sold to farms for animal feeding.

Even though resources and outputs are not specifically included in Figure 5.2.1, the processing system requires various resources as inputs: including energy, water (in the form of liquid freshwater and ice), packaging materials, cleaning agents, cooling agents, and process chemicals. Conversely, apart from the final products, the system can generate several outputs in terms of solid, liquid, and somewhat gaseous waste, as well as energy. For instance, liquid outputs encompass wastewater containing organic effluents, residual cleaning agents, and potential processing chemicals.

Seafood products possess a high perishability factor, necessitating processing for optimal utilization [32]. Seafood processing plants are important, mainly because they aim to improve the shelf life of the products, but also work to give the products a consumption-appealing look, while reducing food loss and food waste. Naturally, seafood processing will have a lot of by-products (bones, shells, heads, etc.), but these are minimized in the processing plants, often by using these byproducts in other animal feed ingredients, biofuel or pharmaceuticals [40]. Human consumption accounts for approximately 75% of global fish production, while the remaining portion is allocated to fish meal and oil production [42].

Seafood processing standards also ensure that responsible practices are being used concerning environmental responsibility, social accountability, animal health and welfare, and food safety, underlining the importance of sustainability in the industry.

MMC First Process [43], a member of the United Nations Global Compact, is committed to championing the Sustainable Development Goals (SDGs) while striving to become a leading entity in effective, meticulous, and sustainable fish processing. Collaborating with industry stakeholders, MMC annually publishes a sustainability report to further these objectives. According to the United Nations Food and Agriculture Organization (FAO) [44], aquaculture is experiencing rapid growth and is projected to account for 60% of the world's fish production for human consumption by 2030, a significant increase of 37% compared to current levels. Recognizing aquaculture as the most sustainable and environmentally-friendly method of food production, FAO asserts its crucial role in meeting the dietary demands of a growing global population, which is expected to increase by 2 billion within the next three decades [44]. Figure 2.3.3 underlines the efficiency of fish production relative to the food conversion ratio (FCR) of meat products. It is a much more efficient method of producing highly nutritious food that contains unique quantities of proteins and ingredients that are key to human health [43].

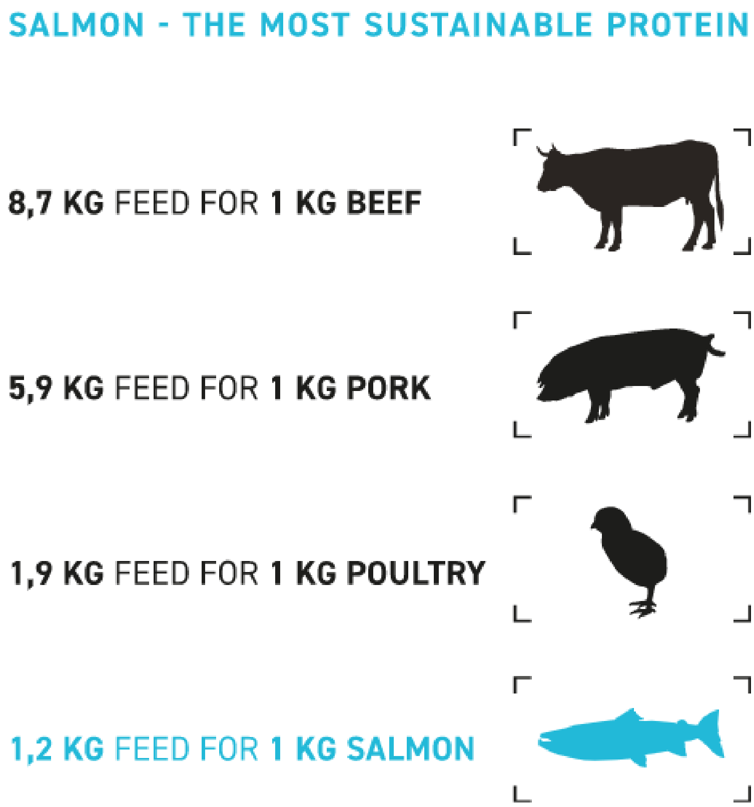

Figure 2.3.3: FCR of fish vs land animals.
The food conversion ratio of fish relative to some land animals [43].

2.3.2 Norwegian Situation

In the context of the master's thesis, it is imperative to emphasize the significance of enhancing fish industry technologies, particularly in the domain of processing, in Norway. Notably, Norway achieved a remarkable feat in 2017 by contributing over 52% to the world's total production of Atlantic salmon. Salmon has emerged as the most extensively farmed animal in Norway, with the industry nurturing more than 837 million salmon in 2021 [45]. Figure 2.3.4 highlights the number of aquaculture sites in Norway, underlining the expansive production levels from a relatively small country.

Figure 2.3.4: Distribution of aquaculture sites in Norway.
(Source: Norwegian Directorate of Fisheries (fiskedir.no).

Presently, fish farming thrives along the vast expanse of Norway's coastline, yielding over 1.5 million tonnes of fish annually, with the majority being exported [45]. However, the exports primarily comprise raw materials and semi-processed products, with only 10-40% of the top seafood products (salmon, cod, and herring) exported as fillets or processed goods. The fish processing industry in Norway is primarily centralized around larger processing companies that possess substantial raw material resources. This approach facilitates enhanced raw material utilization and improved global production efficiency [46]. Given the magnitude of the fish processing sector and the potential areas for improvement, there is a compelling rationale to prioritize sustainability in the processing of salmonids, especially in Norway.

2.3.3 State of the Art

Food processing equipment is an essential part of the food industry, and advancements in technology have led to new equipment that can improve food safety, quality, and efficiency. General trends in the state of the art food processing equipment include adding more automation and digitalization, smart packaging, and of course the implementation of more sustainability. Food processing companies are already adopting sustainable practices to reduce their environmental impact. Some sustainable technologies used in food processing include energy-efficient equipment, renewable energy sources, and waste reduction and recycling.

As will be discussed later, adding automation and following future trends of the industry also add to being more sustainable. State of the art food processors aim to add more automation and digitalization technologies in order to optimize processing parameters, monitor quality, and reduce waste. This includes the use of robotics, sensors, machine learning, data analytics (DA) and internet of things (IoT) [47]. Examples include automated sorting and grading machines that use computer image processing and other advanced technologies to sort and grade products based on size, shape, color, and other characteristics [48].

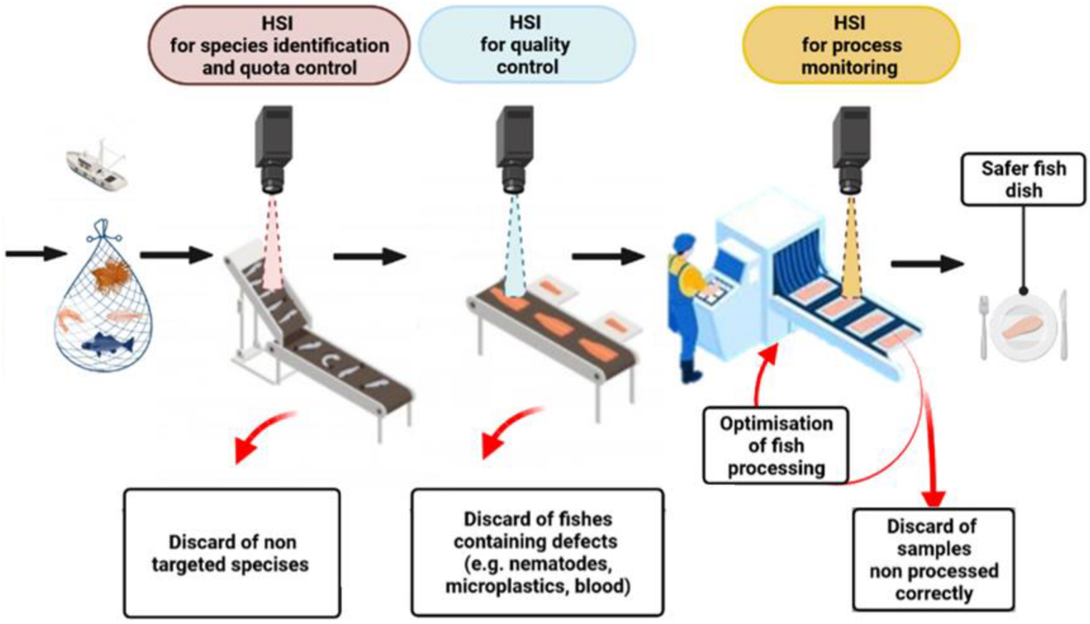

Figure 2.3.5: Examples of HSI application in the seafood sector. Source: Hassoun et al. [49].

Specifically, according to Hassoun et al. [49], the most recent advances in seafood analytical methodology have focused on the application of hyperspectral sensors and advanced mass spectrometry and chromatography techniques. Hyperspectral imaging (HSI) has been used to predict chemical properties, such as fish freshness and basic chemical composition, color and other physical properties of seafood products, as well as microplastic evaluation and microbial spoilage detection. In terms of authentication, HSI has been successful in distinguishing between different fish species and determining the farming system of fish. Furthermore, HSI has shown potential for process monitoring on production lines, allowing real-time measurements and optimization of key process parameters, as shown in Figure 2.3.5. Mass spectrometry techniques have also been utilized for molecular profiling and quality control of seafood products. These techniques offer high sensitivity and the ability to analyze intact tissues or cells, providing valuable information about the presence and distribution of specific compounds.

Other emerging techniques, including Fourier transform infrared (FTIR), Raman spectroscopy, and DNA-based methods, have also been applied in seafood analysis [49]. These advancements in analytical techniques have greatly contributed to improving the quality, safety, and authenticity of seafood products. Adding these techniques therefor provides examples of how new monitoring technologies can add sustainability.

Other current trends of the food processing industry involve using non-thermal processing technologies, including high-pressure processing (HPP), ultraviolet (UV) light treatment and pulsed electric field (PEF) treatment [50] [51]. These are processing methods that gain popularity because of their ability to improve food safety quality without necessarily compromising taste, texture or nutrition, similar to SGS. Other state of the art FPEs that are invested in are continuous thermal processing equipment, such as pasteurizers and sterilizers - used to both heat and cool food products quickly and efficiently [52]. In like manner, these also aim to improve the shelf life of the products while preserving their taste and nutrition. Some of these processing technologies were reviewed in combination with SGS by Esmaeilian [36], and provide examples of the future potential of the SGS technology. As was made clear in section 2.1, SGS as a treatment method could potentially be combined with other technologies while still enhancing value-adding, quality and freshness. In addition, there is a wish to make the SGS equipment as sustainable as possible; not only the treatment that the SGS FPE provides itself, but also the manufacturing and processes related to creating it.

Looking specifically at Atlantic salmonid processing, most of the general objectives of state of the art food processing are relevant, as will be underlined in this study: There is an increased demand for sustainable practices, a rising popularity of value-added products like ready-to-cook and ready-to-eat options [53], and there is a strong interest in technological advancements while enhancing a focus on quality and freshness. Additionally, companies seem to be seeking to expand their presence across the entire value chain, from salmon farming to processing and distribution, hereby creating a need for an integrated approach that allows for greater control over quality and sustainability, as well as traceability [54].

2.4 Tool Limitations

Fundamentally, the limitation of the SDAG tool itself will add constraints in the same way as the project limitations mentioned in section 1.5, because the tool gives the results that the design criteria and requirements are based upon. Ultimately, the limitations mentioned already, exist of limited access to the industry, resulting in the study only being based on the answers from a single employee from each of the companies (the processing company and the FPE manufacturer).

The limited number of stakeholders involved - and therefor an information shortage, may have hindered learning and knowledge gathering, as the SDAG tool was only assessed using two out of a potentially two-digit number of stakeholders. Consequently, the results cannot fully represent the entire industry, and they may be somewhat biased due to the participation of only one employee from each area (processor and FPE manufacturer). It is also important to note that no single employee possesses complete control over all aspects of the company's operations. As a result, certain objectives may remain unanswered or answered without sufficient knowledge to back the responses. For example, a processor working with a trimming machine may not be equipped to address management-related questions, just as an operating chief of a department may not provide the same technical knowledge and results as a working process operator. While some measures have been taken to minimize biases, it is not possible to achieve completely unbiased results in the study. Objectives falling outside the participants' area of expertise are left unanswered and excluded from the results, as well as objectives where the participants have significant uncertainties. This approach ensures that the results are fewer but more accurate. If unanswered objectives were included, they would contribute a 0% rating to the average performance, leading to false results and overall spider plots. This is avoided.

As was concluded in the limitation of stakeholder involvement in section 1.5, by being part of the food industry stakeholders, both the manufacturer and the processor make up some of the most important stakeholders and can cover many of the other stakeholders' views. Even though the operating chiefs of the processing facilities may not provide the same answers as the employees of the facility, they can provide some indications to what the answers would look like. This has been done *to some degree*. However, the limited number of stakeholders and fact that each stakeholder must do the assessment individually and independently, remains a limitation of how the tool is utilized in this study.

CHAPTER
THREE

PRODUCT DEVELOPMENT

3.1 Engineering Design

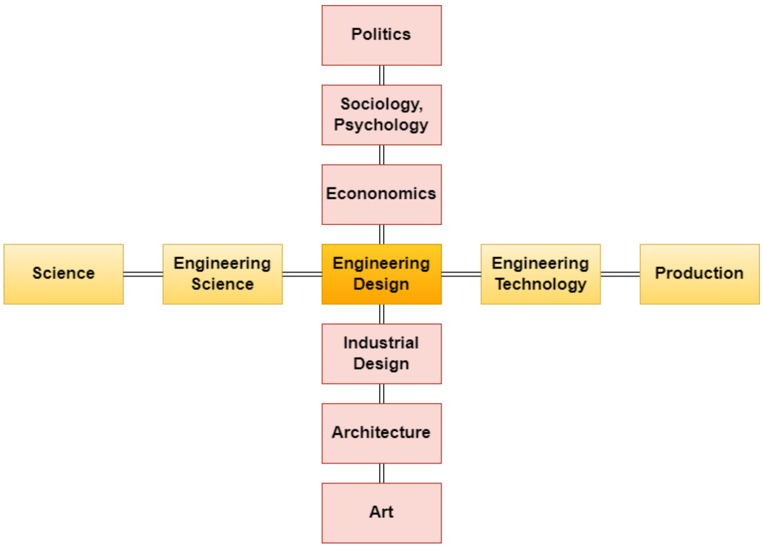

Figure 3.1.1: Engineering Design is cultural and technical:
The model portrays engineering design, according to Dixon [55] and Penny [56].

Designing can involve either addressing a specific problem, or devising a plan to fulfill a particular requirement. When this plan results in the creation of something having a physical reality, then the product must be **functional, safe, reliable, competitive, usable, manufacturable, and marketable** [57]. Design is an innovative and iterative decision-making process. In *engineering* design, basic sciences are combined with applied mathematics and engineering in order to convert resources until they meet a stated objective. To reach a design objective, the designer must also remain within the constraints, often set by material, technological, economic, legal, environmental and human-related considerations [58]. There are frequently, multiple stakeholders to consider and respect, as indicated by the flowchart in Figure 2.2.2. There are multiple models on what 'Engineering Design' really is. One of those models is shown in Figure 3.1.1 where engineering design is put at the intersecting cross point of a cultural and technical stream.

According to Pahl et al. [58], **design is an engineering activity** that:

- Affects almost all areas of human life,
- Uses the laws and insights of science,
- Builds upon special experience,
- Provides the prerequisites for the physical realisation of solution ideas,
- Requires professional integrity and responsibility.

Convincingly, understanding the essence of "engineering design" is crucial when embarking on the journey of developing a new product. By immersing themselves in the principles and practices of engineering design, designers and developers acquire invaluable knowledge and a comprehensive toolkit that empowers them to skillfully navigate the intricate terrain of new product development (NPD). Knowing what engineering design is, the designer can systematically analyze problems, explore innovative solutions, optimize designs, and anticipate potential challenges [59]. It can also foster collaboration among multidisciplinary teams, facilitate effective communication, and cultivate a culture of continuous improvement in such a way that the pursuit of excellence in engineering design serves as an industry progress driver and catalyst for transformative advancements [60]. The recognition of the significance of engineering design empowers organizations to unlock the full potential of their innovative visions and bring impactful products to life. The knowledge learned from engineering design, not only enhances the efficiency and effectiveness of the development process, but also contributes to the creation of products that excel in functionality, reliability, user satisfaction - and possibly sustainability.

In fact, the United Nations Educational, Scientific and Cultural Organization (UNESCO) released a paper in 2021 called "Engineering for sustainable development: delivering on the Sustainable Development Goals", where it is stated that engineering is **crucial** for the advancement of each of the Sustainable Development Goals (SDGs) [61]. The paper highlights the importance of engineering design in transforming the world through development of new technologies, having a significant impact on economic growth, quality of life and environment. It also lists examples of how engineers can make each SDG happen and come true.

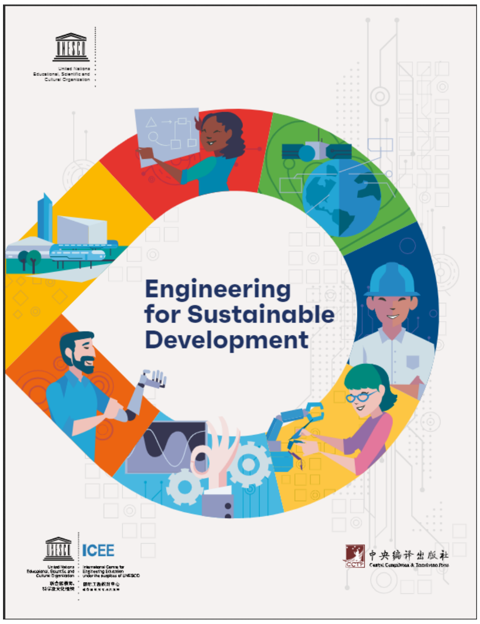

Figure 3.1.2: The front page of the UNESCO report: *"Engineering for Sustainable Development"*. [61].

3.2 Set-Based-Inspired Systems Engineering

3.2.1 Concurrent Engineering

Design objects have both a physical nature and an intentional nature [62], meaning that design is done to *intentionally* give something *physical* form with a goal in mind. Traditionally, a product's *physical nature* refers to its shape and substance, while its *intentional nature* is determined by the function it performs. However, these natures are often ambiguously defined, leading to conflicting perceptions and miscommunication in the design process [63]. The term *"Concurrent engineering"* originates from the viewpoint that the natures of a product go beyond those definitions, by also considering aspects like comfort, cost, sustainability, aesthetics, etc. Concurrent engineering necessitates designers to have an extensive viewpoint on the product, integrating all crucial lifecycle phases and intentions, to maximize the completeness and accuracy of information guiding design decisions [64].

Simply put, concurrent engineering is a holistic approach to product development, where multiple process stages run simultaneously, encouraging consideration of all aspects of a design throughout its life [65]. Moreover, the typical involvement of multiple stakeholders necessitates the consideration of multiple preferences. Conclusively, it emphasizes parallel and collaborative involvement and promotes early and continuous communication, coordination, and integration of different teams, such as design, manufacturing, marketing, and suppliers.

An overall goal of NPD is to minimize the time required to bring a product to market, improve the quality of the product, and optimize general efficiency. This can be achieved by proactively identifying and resolving potential issues early in the development process by facilitating prompt decision-making. Concurrent engineering plays a pivotal role in such an approach by efficiently managing the entire product lifecycle, accomplished by promoting collaboration among various functional teams and facilitating iterative design enhancements - overall minimizing the time required, as shown in Figure 3.2.1.

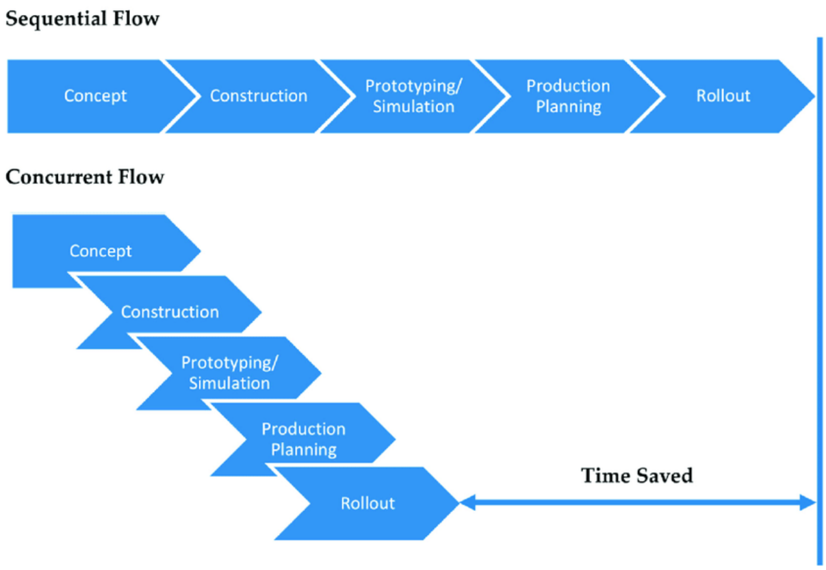

Figure 3.2.1: An image highlighting the effect of concurrent engineering. Source: Gielisch et al. [65].

3.2.2 Systems Engineering

On the other hand, *systems engineering* (SE) takes a broader perspective by considering the product as an integrated system within its larger context. It encompasses the systematic approach of identifying, analyzing, and managing complex interactions between the product's components, subsystems, and its environment. Systems engineering seeks to ensure that the product meets its intended purpose while satisfying user requirements, performance specifications, safety regulations, and other relevant constraints. It also involves a holistic view of the product, encompassing not only its technical aspects but also factors such as cost, schedule, reliability, maintainability, and sustainability. SE is a well-established set of practices that address the lifecycle of a system or a product [37]. In essence, concurrent engineering emphasizes the collaborative aspect of product development, while systems engineering focuses on the comprehensive analysis and management of the product as a complex system [66]. Both approaches are complementary and aim to enhance the effectiveness and efficiency of the engineering process, albeit with slightly different focuses and perspectives.

According to Fraser and Gosavi [67], the word "system" in systems engineering is meant to remind industrial engineers of three key points to emphasize:

1. **Components** (including machines and people) interact with each other to create the overall behavior of the system;

2. The system being studied is always a **subsystem** of a larger system and these interactions must also be considered;

3. Systems include **humans**.

The field of systems engineering encompasses various definitions, often being categorized as sub-fields of electrical engineering, industrial engineering, engineering management, or technology management. For example, NASA incorporates systems engineering in their research and development efforts, where it is viewed in the context of overall project management [68].

Considering the objective of this chapter, which is to present the product development method employed to achieve SGS design concepts, it is pertinent to introduce the process of SE. While SE is theoretically a comprehensive and holistic approach, it remains crucial for developers and designers to comprehend its significance within the broader context of "engineering design." This understanding is essential to maintain a clear analytical methodology. Furthermore, in the context of introducing the overall product development approach used in this study, it is important to familiarize oneself with related concepts such as concurrent engineering, systems engineering, and lean product development (LPD) (subsection 3.2.3. Although the concept development project is primarily conducted individually throughout the duration of the master's thesis, it remains crucial to introduce concurrent engineering and SE methodologies as they play key roles in future product development processes. As mentioned, there is a desire for the stakeholders depicted in the flowchart of Figure 2.2.2 to collaborate within a multi-stakeholder environment, rather than conducting their evaluations independently as currently practiced.

While much of the product development approach is inspired by the set-based method, it is important to have a systems engineering management. Figure 3.2.2 shows the essence of a systems engineering process and management [69]. This emphasizes the three activities that are necessary to achieve proper management of a development effort, and underline why it is necessary for a developer to know the principles of systems engineering:

- Development phasing that controls the design process and provides baselines that coordinate design efforts.
- A systems engineering process that provides a structure for solving design problems and tracking requirements flow through the design effort.
- Life cycle integration that involves customers in the design process and ensures that the system developed is viable throughout its life.

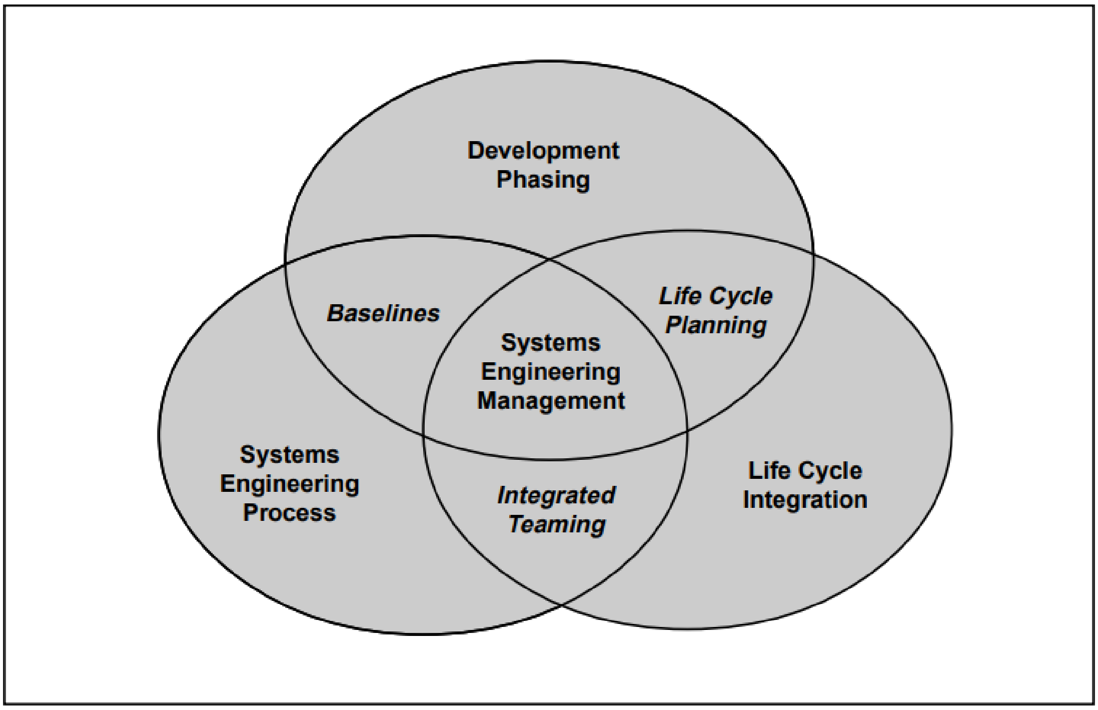

Figure 3.2.2: Three activities that make the scope of Systems Engineering. Source: DEFENSE ACQUISITION UNIVERSITY PRESS [69].

Again, the primary focus of the thesis revolves around concept development rather than the entire product development process. While certain terms in Figure 3.2.2 have been evaluated, "integrated teaming" remains unallocated in the overall objective of achieving comprehensive SE management. However, there is potential for future product development phases to incorporate all elements that constitute the SE management. Nonetheless, valuable insights can still be derived from the principles of the SE management method in the present context.

3.2.3 Set-Based Design

Set-based design (SBD), sometimes referred to as set-based concurrent engineering (SBCE), has emerged as an important component of lean product development (LPD) with all researchers describing it as a core enabler of LPD [70]. LPD, initially observed in the Toyota Product Development System [71], has evolved from incorporating lean manufacturing principles to becoming a distinct approach in engineering. It encompasses key principles such as waste reduction, value- and knowledge-focus, and flow optimization [72]. Numerous models and frameworks have been developed to enable the practical implementation and continuous research of LPD. Despite its benefits, the industry's adoption and implemtation of LPD often remain at an introductionary level, with few companies effectively combining LPD enablers to improve their product development processes in a lean manner. However, SBD, as a role within LPD, has been more efficient as a product development method and can serve as an analytical and clear approach in new product design.

Set-based design (SBD) is a valuable approach for enhancing flexibility and minimizing rework in the development process. Early implementation of set-based practices helps reduce rework by front-loading critical decisions and addressing root causes. The three primary causes of rework include: late learning, premature design decisions, and poor cross-functional coordination [73]. When a previous decision, assumed to be final for the project, needs to be altered due to later discoveries of defects, rework is doomed to happen. To overcome these challenges, generating essential knowledge through detailed design work becomes crucial, requiring prior concept and systems design decisions. Accelerated learning is achieved by integrating efficient learning, for instance through use of limit curves, as observed initially in the Wright Brothers' systematic and innovative design of experiments (DOE) - a testing approach in the early days of aerospace engineering [73] [74]. Delaying critical decisions until sufficient knowledge is acquired involves defining set-based requirements, specifications, and management [73].

The main goals of the introduced product development methods are to generate necessary knowledge before making key decisions, breaking circular dependencies. Set-based design addresses this objective by representing initial requirements as "sets," imposing constraints, and gradually narrowing down the available design alternatives.

Figure 3.2.3 presents a conceptual framework that demonstrates the application of set-based design (SBD) across the entire system design lifecycle. The process commences through identification of the needs and requirements, serving as guiding factors for all subsequent design stages in Figure 3.2.4. The framework progresses from the exploratory, concept and development phase, where each phase incorporates design and analysis techniques, of which there are many, especially model-based [75]. Keep in mind that also a stakeholder analysis was done for the in-depth study [2].

Originally, the set-based design process is done in teams, where the team (1) defines sets of solutions at the system level, (2) explores various subsystem-options in parallel, (3) applies analyses to refine the alternatives, (4) converges towards a single solution, and finally (5) ensures minimal changes once it is established.

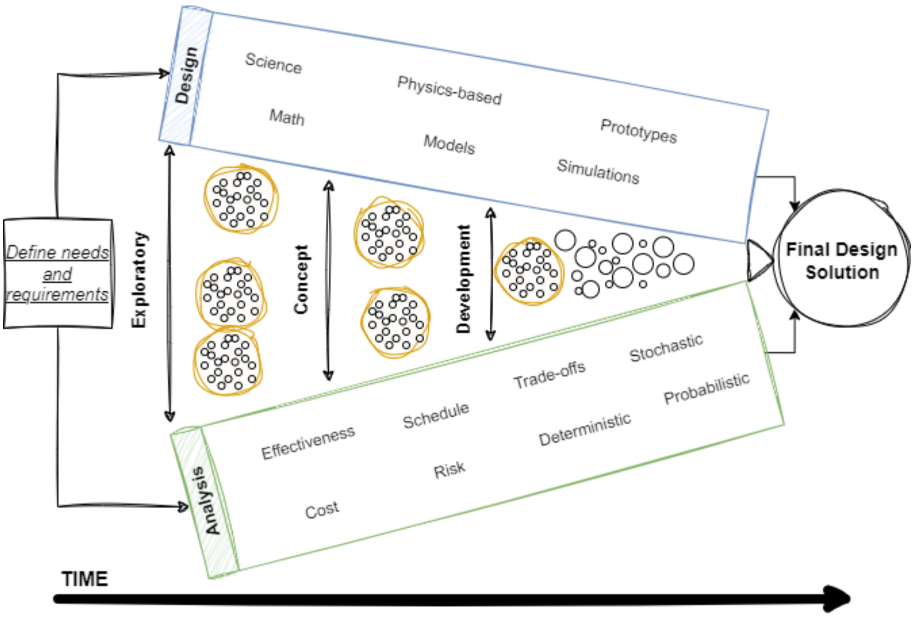

Figure 3.2.3: A conceptual framework of SBD.
Adapted from Specking et al. [75]

Such a process is shown in Figure 3.2.4. Employing set-based practices in conjunction with concurrent engineering fosters collective work for the rework prevention, enabling team members with varying expertise to apply key sets and limit curves efficiently and effectively. Furthermore, wider sets of specifications agreed upon by the team leave more design space for potential downstream teams. With SBCE, the analysis activities presented in Figure 3.2.3 can be conducted concurrently, allowing for efficient integration throughout all phases of the process.

The three principles of set-based concurrent engineering (SBCE), as described by Sobek, Ward, and Liker in 1999 [71], have consistently remained unchanged in both research and industrial applications, as noted by Ghosh and Seering [76]. They consist of the following principles:

1. Map the design space
   - Define feasible regions
   - Explore trade-offs by designing multiple alternatives
   - Communicate sets of possibilities
2. Integrate by intersection
   - Look for intersections of feasible sets
   - Impose minimum constraints
   - Seek conceptual robustness
3. Establish feasibility before commitment
   - Narrow sets gradually while increasing detail
   - Stay within sets once committed
   - Control by managing uncertainty at process gates

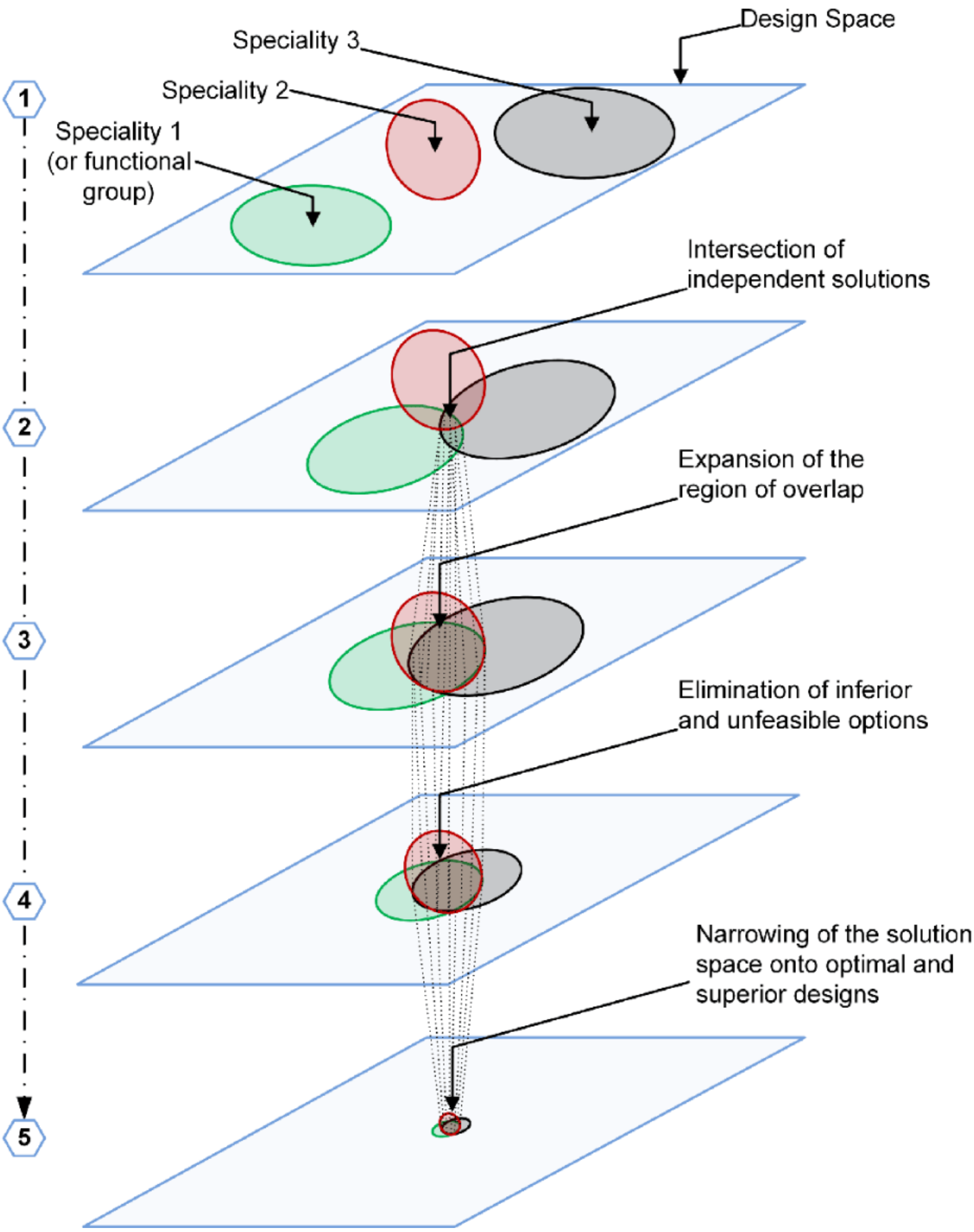

Figure 3.2.4: A figure showing the SBD approach to PD.
Adapted from: Bernstein [77].

Even though the described collective team-work in original set-based design has not been adapted for the concept development of the study due to lack of team members, there is inspiration to be drawn from the set-based design method. Primarily, in mapping the design space, finding possible solutions and possibly utilizing their intersections until a final solution can be singled out. Additionally, the early, detailed identification of needs and requirements as well as the use of models and analyses will be used in the approach of concept development of preliminary SGS designs. Rework should be reduced, and employing set-based practices together with gated processes (e.g. stage gate [78]), a spiral model (iterative) [79] or a design structure matrix (DSM) [80] further aids in that reduction. In the case of the thesis, inspiration is drawn from the set-based approach only in the concept phase, so many of the practices can still be applied for future phases of the design development.

Naturally, the design of complex engineered systems requires detailed analyses performed by a large number of experts over a specific period [75]. Additionally, real-world complex systems have non-linear design spaces, making it difficult to find the true map of specialities and constraints. Even though a set-based design approach is efficient in considering multiple alternatives, determining feasibility and requirements and thereby narrowing down into the best possible solutions, is not always the best practicable method. Nevertheless, it is once again important to note that the current approach merely takes inspiration from the method, and a significant portion of the commonly employed practices, models, and analyses that constitute the framework of SBD are yet to be executed. Moreover, when considering multiple alternatives in practice, e.g. by using set-based prototypes [81], it can create very high demands in terms of costs, resources and time - but in the case of this study, so far, the concept phase has had no use of prototypes considering the size of the equipment, meaning that no resources are wasted. However, it could potentially be a constraint in the future.

For the concept development in the thesis, the feasible regions and requirements are already somewhat known due to previous research and literary reviews. The set-based design method is therefor only used to some degree in the way that multiple ideas are considered from the initial concept phase, until the most important requirements are found, and the feasible areas are narrowed. It is however important to understand and utilize SBD as an approach since it can become the reason to increased flexibility, minimized rework, integration of cross-functional expertise, efficient decision making and improved innovation - all important factors of the concept development project.

3.3 Sustainability-Added Design

3.3.1 Sustainability-Oriented Innovation

Innovation refers to the application of better solutions that fulfill new requirements, inarticulated/unspoken needs, or existing market demands [82]. According to Zhang et al. [83], the understanding of *design* should be seen from the *designer, design process and context*, while *innovation* should consider *innovative ideas, people, context and knowledge*, but the two definition are very much intertwined. A target of this study is therefor to develop an *innovative sustainable design*.

For an innovation to be considered sustainable, it should be new, useful, and effectively utilized. Sustainable-oriented innovation (SOI) encompasses three sustainability orientations (sustainability-relevant, sustainability-informed, and sustainability-driven), four dimensions of innovation (technological, organizational, institutional, and social), two natures of innovation (sustaining and disrupting), and two rates of change (incremental and radical) [84]. The fundamental challenge of sustainable development, and the driving force behind innovation, lies in the potential arising tension from pursuing multiple sustainability goals simultaneously. Therefore, a solid tool and approach is vital.

According to Adams et al. [85], innovators define the three orientations to sustainability as follows:

- **Sustainability-Relevant innovations (SRI)** referring to environmentally beneficial normal innovations where sustainability serves as a positive side effect.
- **Sustainability-Informed innovation (SII)** encompassing innovation processes that do not primarily target sustainability issues but consider sustainability in their approach
- **Sustainability-Driven innovation (SDI)** explicitly aims at achieving sustainability goals, with the innovation driven by the need to solve societal and/or environmental problems.

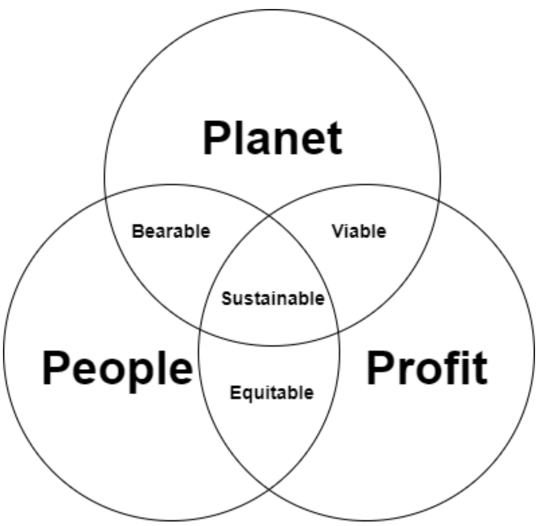

Figure 3.3.1: The triple bottom line.

When developing a new product with the goal of maximizing sustainability, SOI becomes highly relevant. A new product itself represents an innovation, and sustainability can be incorporated either directly or indirectly, with a preference for direct integration. Sustainable development is a concept with various definitions, but the consensus lies in the understanding that the world must undergo significant change. One widely recognized framework for sustainability in product development is the "triple bottom line" introduced by Elkington in 1994 [86]. It emphasizes the three interconnected areas of People, Planet, and Profit, as depicted in Figure 3.3.1, often referred to as the three pillars of sustainability [87]. This framework acknowledges the interdependency between society, economy, and the planet's natural resources. It highlights that social and economic progress must respect environmental boundaries. The SDAG tool used in the study aims to capture all these dimensions of sustainability, including environmental, social, and economic aspects, while also considering future considerations - aiming to make a new product futureproof.

Achieving more sustainable products requires a careful balance between environmental protection, social equity, and economic prosperity, while addressing customer and market needs [88]. This must be done with a forward-thinking approach, giving due consideration to future implications. Innovation, encompassing SRI, SII, and SDI, plays a crucial role in driving sustainability and striving for optimal solutions that align with the triple bottom line framework.

3.3.2 Design for Environment

The methodology known as "Design for X" (DfX) is a widely recognized approach in function-oriented design. It enhances the attribute information of design solutions to achieve specific goals. Similar to other product development processes mentioned earlier, DfX serves as a tool for evaluating design solutions and documenting the process evolution. It facilitates rationalizing decisions and comparing alternative solutions [89]. DfX operates systematically and proactively, offering designers and engineers clear guidelines. In the context of DfX, the "X" represents a specific virtue that the product should embody (such as quality, cost, environment, safety, maintainability, and reliability) or a particular life phase it should address (such as manufacturability, assembly, transportability, usability, and recyclability) [90]. Alternatively, DfX is sometimes referred to as "Design for Excellence" [91]. Each DfX method provides metrics that assist designers in developing products that excel in the specific aspect under consideration, the "X". DfX methods contribute to design improvement in two key ways: by raising awareness and making designers conscious of the important virtues or life phases they need to consider, and by providing decision support through tools for evaluating designs from the given perspective (such as metrics, guidelines, and feasibility checks).

In this study, the main focus is on "design for environment", reflecting a shift in engineers' concerns over the past decades. While traditionally, properties such as costs, performance, and reliability have been emphasized, there has been an increasing interest in reducing the environmental impacts of processes and products [92], making Design for Environment (DfE) highly relevant. The DfE approach brings together a wide range of stakeholders [93]. McAloone [93] argues that incorporating "environmental protection" as a design goal requires a whole-life approach, addressing the environmental performance of a product throughout its life cycle, rather than dealing with the goal at one specific point in the design process. DfE has gained significant traction today, with numerous examples of multi-stakeholder collaborations aimed at improving environmental impact. Notably, the Sustainable Development Goals (SDGs) initiated by the European Commission in 2017 serve as a high-level multi-stakeholder platform, involving stakeholders from civil society, non-governmental organizations, and the private and corporate sectors to support and advise the European Commission on SDG implementation at the EU level [94]. Furthermore, URBACT, co-founded by the European Union, established a toolbox in 2019 on setting up and managing multi-stakeholder groups [95]. Consequently, it can be argued that the Stakeholder-Driven Analysis and Generation (SDAG) tool introduced, aligns with the principles of DfE, considering all stakeholders.

Despite the potential benefits, Lindahl [31] found that DfE methods and tools are rarely used by industry designers due to perceived lack of time and usefulness in everyday work environments characterized by limited resources and tight deadlines. Similarly, Bar [32] investigated the experience of food processing developers with DfE methods and discovered that none of the studied companies employed DfE methods or tools, very much in compliance with the limitation mentioned in subsection 1.5.4. In addition, their assessment of environmental aspects of processing machinery using Life Cycle Assessment (LCA) revealed a limited understanding of how the design of such machinery could impact the environment beyond basic resource and energy consumption. Although some improvements may have occurred in the industry since the publication of this report in 2015, as the in-depth-study highlighted, the current conditions necessitate further development of environmental design guidelines. These guidelines should be easily adaptable, understandable, and implementable in the design process, ensuring the seamless integration of environmental considerations into new product development.

Keep in mind that even though the main focus is on Design for Environment here, the overall approach related to the study is Design for Sustainability. This means combining Design for Environment with Design for Society and Design for Economy (see Figure 3.3.1, among others.

There is a clear impediment in combining DfX methods, or hereby combining DfX with concurrent engineering. All of the DfX methods have been individually created with their own complexities and their own required substantial research. However, in order to satisfy concurrent engineering, the methods must be integrated with broader product development and not applied in isolation. Since each DfX method aims to improve a product from only one viewpoint, it restricts the designers' view to a single aspect of the product's intentional and physical nature and provides no reference to the bigger picture of the products purposes - ultimately making the design less holistic. The different DfX methods are difficult to incorporate into the holistic view encouraged by concurrent engineering. Meaning, relationships between DfX methods and their links to the design process as a whole needs consideration for DfX methods to be applied in practice.

Conclusively, while DfX methods are rarely implemented and have their limitations is combination with each other or with concurrent engineering, the introduction of DfX holds significant relevance for the case study; particularly in the context of introducing Sustainability by Design. Sustainability by Design can be viewed upon as a combination of sustainability-oriented innovation and the DfX method Design for Sustainability. The framework encompasses a holistic perspective that integrates environmental, social, and economic considerations into the product development process.

3.3.3 Sustainability by Design

While DfX methods like design for environment or design for sustainability aim to design something with the specific aim of the its virtue or lifephase, the study aims to design something while considering sustainability, among others. As a matter of fact, the objective is to create sustainability guidelines from designing (sustainably), as opposed to only designing from sustainability guidelines. Albeit inspired by a combination of Design for Environment and sustainable innovation, the main approach is not Design for Sustainability, but *Sustainability by Design*.

The concept of Sustainability by Design is one that has been around for a long time. A great example of description and utilization of Sustainability by Design was created by the International Union of Architects (UIA) in 2009. To implement the Sustainable by Design strategy, the UIA Council formed an international project team of 124 member countries to develop practical methods and guidelines for integrating sustainability principles into construction projects. The Sustainable by Design Mission was launched at the UIA World Congress in Tokyo in 2011 and formally adopted at the 2011 UIA General Assembly [97]. Some keypoints to take away from the UIAs Sustainability by Design strategy include:

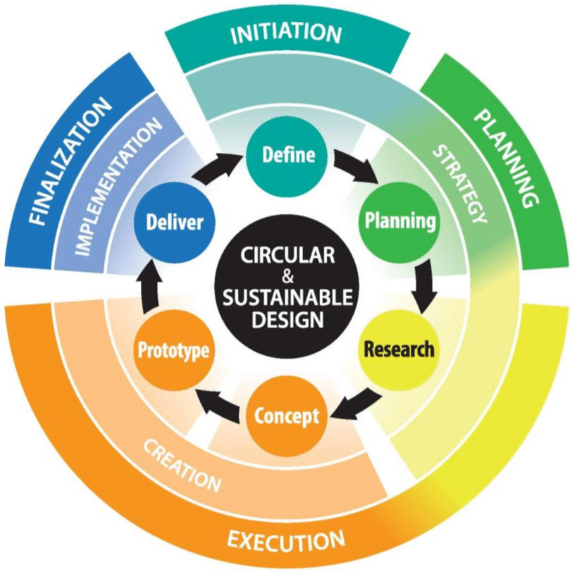

Figure 3.3.2: The planned time-model for sustainable-by-design adaption.
Source: Camocho, Vicente, and Ferreira [96].

- **Early Stage Commitments and Collaboration:** Sustainable by Design emphasizes the importance of engaging all stakeholders from the earliest stages of a project. This commitment fosters collaboration and ensures that sustainability considerations are integrated into the project's vision, goals, and decision-making processes.

- **Life Cycle Analysis and Management:** The strategy adopts a holistic approach by considering the entire life cycle of a project. It encompasses the environmental, social, and economic impacts associated with construction, operation, and decommissioning. By conducting comprehensive Life Cycle Analysis and Management, sustainable practices can be identified and implemented throughout the project's lifespan.

- **Efficiency Optimization through Design:** Sustainable by Design seeks to optimize efficiency through thoughtful design. By integrating renewable energies, high-performance technologies, and environmentally benign practices, projects can achieve maximum energy efficiency and minimize resource consumption.

- **Integration into the Surrounding System:** Recognizing that projects are part of a complex interactive system, Sustainable by Design acknowledges their link to the natural surroundings and their influence on the heritage, culture, and social values of the community. This approach ensures that projects harmonize with the existing context, promoting a sense of place and enhancing the overall well-being of the community.

- **Health-conscious and Respectful Approach:** Sustainable by Design prioritizes the selection of healthy materials that contribute to the creation of safe and comfortable buildings. It also emphasizes ecologically and socially respectful land-use practices, promoting sustainable development and preserving natural resources. Moreover, the strategy recognizes the significance of aesthetic sensitivity in inspiring and enriching the built environment.

- **Reduction of Adverse Impacts:** The strategy sets ambitious goals for reducing the carbon footprint, minimizing the use of hazardous materials and technologies, and mitigating other adverse human effects on the natural environment. By adopting sustainable practices, projects can minimize negative impacts and contribute to the preservation of the ecosystem.

- **Improving Quality of Life and Promoting Equity:** Sustainable by Design aims to enhance the quality of life for individuals and communities. It promotes equity on both local and global scales, advancing economic well-being and creating opportunities for community engagement and empowerment.

- **Local and Planetary Interdependence:** Acknowledging the interdependence of all people, Sustainable by Design recognizes the need for an integrated, sustainable rural-urban system. It highlights the importance of clean water and air, access to food, shelter, work, education, health services, and cultural opportunities in supporting urban populations.

- **Cultural Diversity and Creativity:** Sustainable by Design endorses UNESCO's perspective on the significance of cultural diversity. It recognizes the exchange, innovation, and creativity that arise from diverse cultural perspectives, considering them as essential for the well-being of humankind, just as biodiversity is crucial for nature.

The Sustainable by Design Strategy is a comprehensive approach that places sustainability at the forefront of construction projects for the Union of Architects. Looking away from construction, the strategy is absolutely transferable to any other project, especially product development. It recognizes the need for collaboration and commitment among stakeholders, including clients, designers, engineers, authorities, contractors, owners, users, and the community - in this case the food processing industry. In sum, all the stakeholders depicted in Figure 2.2.2. The keypoint of "Integration into the surrounding system" also has its clear relevance to systems engineering (subsection 3.2.2). For the "Local and Planetary Interdependence" - keypoint, as well as the "Cultular Diversity"; it could be transferred to having a safe, secure and open work environment. By incorporating all aspects of construction and future use, based on full Life Cycle Analysis and Management, Sustainable by Design aims to optimize efficiency, minimize adverse environmental impacts, and enhance the quality of life.

Figure 3.3.2 showcases a circular model of sustainable design. While the definition (initiation), planning and somewhat research phase has been done, the project is now arriving at the concept phase, where execution and creation is just getting started. These phases can be linked to the previously introduced "exploratory" and "concept" phases of SBD in Figure 3.2.3. Keep in mind that the design process of the study is not circular like in the model, but the process phases are otherwise aligned.

Figure 3.3.3 shows a guidance list of sustainable by design dimensions *"intended to be used by innovators within chemical companies"* created by The European Chemical Industry Council (Cefic) [98]. Looking at this figure, as well as the initial strategy of sustainability by design, it is evident that the SDAG tool used in this study has been created in such a way that all dimension have been covered. In fact, today, the UIA have an own SDG commission in order to implement sustainability in architecture. With this in mind, a clear strategy, and a tool to aid with utilizing the strategy, the concept development and creation of sustainability guidelines can take place.

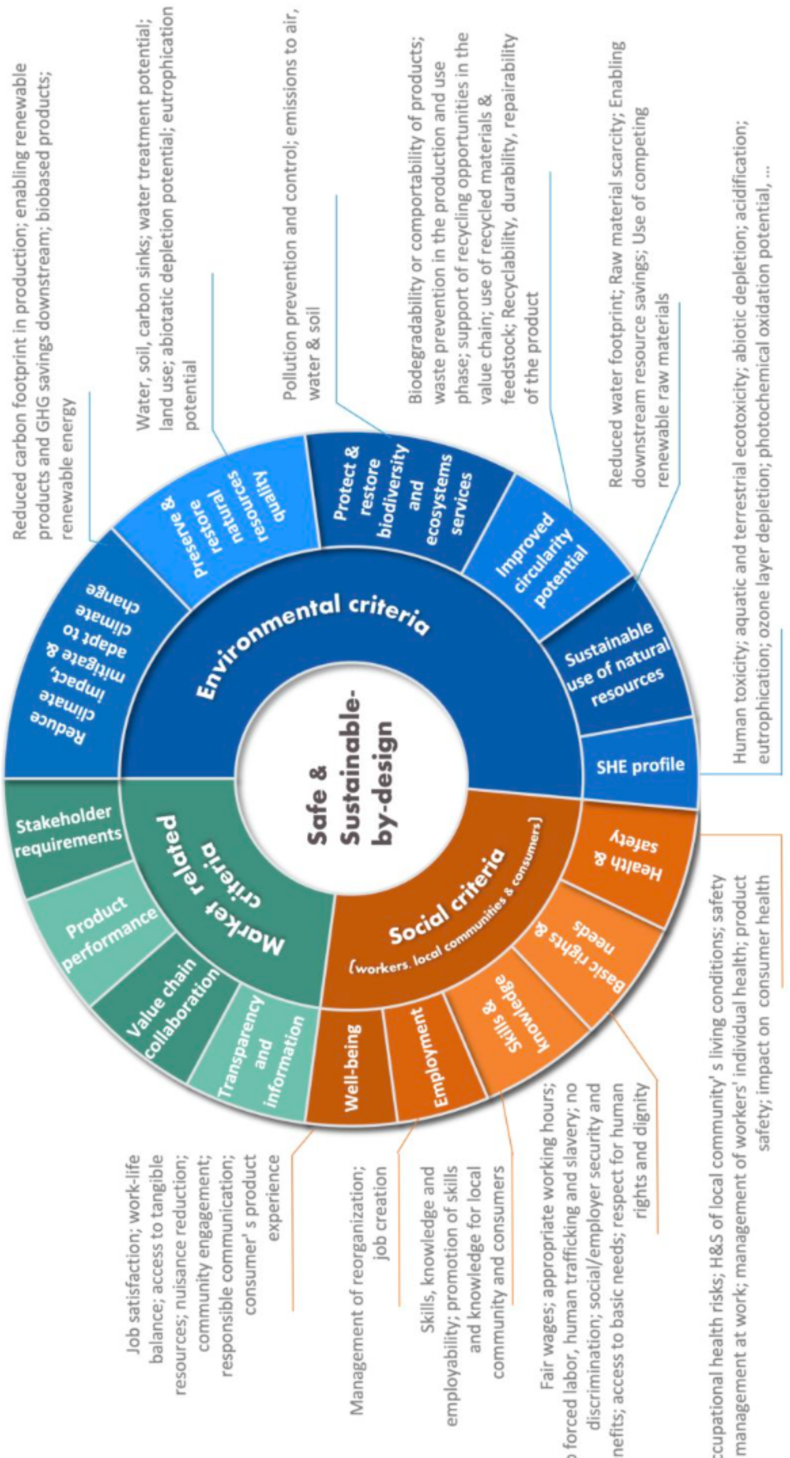

Figure 3.3.3: The dimensions to consider in sustainable-by-design: A comprehensive, yet not exhaustive list of safety and sustainability aspects to assess and design sustainable chemicals, materials, products and processes according to The European Chemical Industry Council: Cefic [98].

3.4 Multiple-Criteria Decision Making

The SDAG tool presented in the in-depth study, and shortly recalled in section 2.2 will provide an overview of how sustainability objectives are weighted and evaluated. The tool will provide information on whether to act or not to act on the objective based on the evaluation. However, the objectives are not a list of improvements areas ranked by priority. As stated by the creators: *"Such a list must be compiled by the analysts. Risk analysis or multi-criteria analysis can be performed to refine improvements ranking"*. (Villeneuve et al. [34]). As was mentioned in subsection 3.2.3, efficient decision making is crucial in early design details.

Multiple Criteria Decision Making (MCDM) is a collection of analysis methods. After a selection of criteria are identified, weights of resources are given to the criteria, and thereafter the resources should be ranked given a specific MCDM method [99]. The different methods are recognized as primary approaches for decision-making that take into account multiple criteria. Classification of MCDM methods can be done based on many different aspects, and some are more used than others, in all types of fields and industries. While no completely specific MCDM method has been chosen for the study, it is important to note that a prioritization has to be made after the design criteria have emerged from utilizing the SDAG tool. The approach used is most similar to SMART MCDM [100], as the prioritization will be based on evaluating the criteria using the importance evaluation. The importance is found through the weighting in the assessment tool, but is also determined by extra interviews with the manufacturer, and "other requirements" (subsection 4.3.3) to differentiate two objectives scoring likewise. The approach of multi-criteria decision making works by creating trade-offs and utilize these to form an order of significance and importance within the many criteria.

CHAPTER

FOUR

PRODUCT REQUIREMENTS

4.1 Initiating Concept Development

As touched upon in both section 2.1 and subsection 2.3.3, SGS is a constantly developing process with great potential. This thesis is part of the Research Council of Norway's project "Concept development of full-scale soluble gas stabilization (SGS) technology for seafood" started in 2018 [101], and a natural point has been reached for concept development to take place, after multiple years of research and planning.

The target for this concept development project is specifically to look at the inlet and outlet of the potential SGS processing equipment. While the results will be useful for future research in the way that different solution alternatives are explored, some simplifications are made. As opposed to product development, the product or service is not necessarily made physically, but it is explored in theory. According to Branch and Rocchi [102], *"Concepts serve critical functions in science, through their descriptive powers and as the building-blocks of theory"*. When exploring various design theories and methodologies (DTMs), it is clear that most methodologies share some common characteristics, namely that they consist of a sequence of phases from concept till detailed design, with clarified goals and established product specifications [103]. For instance, the famous recipe-driven Pahl and Beitz [89] design approach is based on elaborate analysis of the fundamentals of technical systems. It consists of four main phases: (1) planning and clarification of the task, (2) conceptual design, (3) embodiment design, and (4) detail design. Another example is from Ulrich and Eppinger's *"Product Design and development"* [104], which is considered the state of the art when is comes to modern systematic design - that is not *too* systematic. The method consists of six main stages: Planning, concept development, system-level development, detail design, testing and refinement, and production ramp-up. It uses a practically oriented concept development approach with functions and combinations into concepts. As can be seen in Figure 4.1.1, concept development is a significant phase of product development.

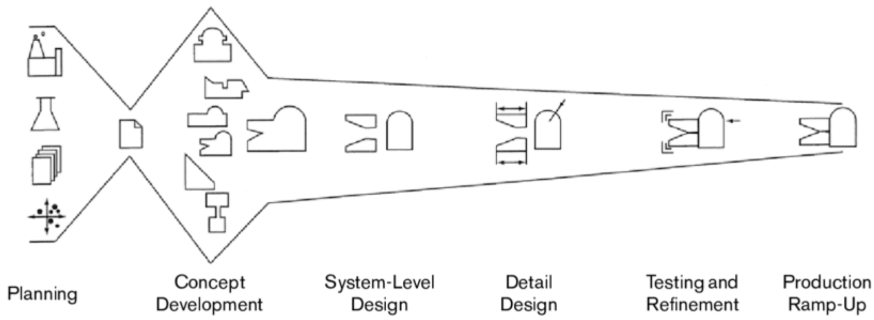

Figure 4.1.1: The generic product development process of Ulrich and Eppinger [104].

By examining these examples, the significance and breadth of the concept development phase become apparent.

Looking specifically at the SGS concept development, the focus is put on the inlet and outlet of the SGS processing equipment, because this is were the most obvious bottlenecks would be in the product development. When focusing on sustainability implementation in NPD, it is prudent to examine these components. This is motivated by the fact that since the SGS process involves the utilization of carbon dioxide CO_2, there exists a potential risk of gas leaks that must be mitigated to ensure sustainability and minimize environmental impacts. As a result, the SGS Food Processing Equipment will require the inclusion of a designated CO_2 gassing area, equipped with inlet and outlet components designed to allow the entry of fillets while preventing the escape of gas.

In order to develop the concept of SGS further, the plan is to use the approaches from subsection 3.2.3 and section 3.3: set-based and sustainability-added. Using research from earlier stages of the full project, multiple solutions can be explored. By using inspiration from the set-based systems engineering, and defining specific requirements, a potential final concept could be reached, while also using sustainability implementation guidelines. As the main focus for this concept development lies in the inlet and outlet components of SGS, it is natural to also look at examples of physical objects with similar components and gas emission possibilities, for concept inspiration. Some of these include multiple CO_2 storage/injection/capture technologies [105] [106]. Inspiration can also be drawn from CO_2 incubators, Euthanasia chambers, water carbonating machines, alcoholic beverage fermentation [107][108] and airlocks used in underwater and extravehicular activities - like the one shown in Figure 4.1.2.

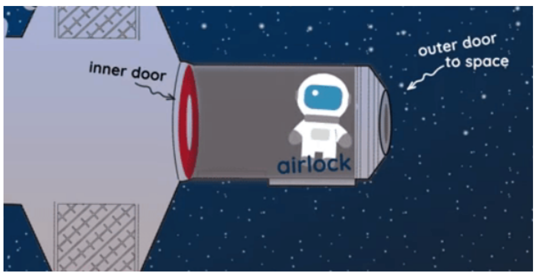

Figure 4.1.2: A simple showcasing of airlocks in space applications. Adapted from ESA [109]

4.2 Identifying the Design Criteria

Looking back at Figure 3.3.2, the initiation and planning part is completed, while the execution part is close to becoming concept development. To finish off the research phase, the requirements for the SGS concept are defined through an analysis of what is expected from an FPE. Additionally, these requirements should include specific sustainability requirements. To decide on the requirements, results from the in-depth study for the thesis [2] will be used. Additionally, the tool from this study will be somewhat modified and reused in collaboration with another stakeholder; an FPE manufacturer.

4.2.1 Utilizing the SDAG tool

In accordance with the content in section 2.2, an extensive examination was conducted employing an SDAG assessment tool rooted in the United Nations' Sustainable Development Goals (SDGs). The purpose was to ascertain the sustainability objectives pertinent to the industry. Notably, the tool was employed in conjunction with a stakeholder from the processing facility, more particularly an operations manager in the filleting department. The findings of the study emphasized that in order for a new fish processing equipment design to contribute to more sustainability in the food processing industry in Norway, it is imperative to invest greater efforts in the implementation of innovative sustainable practices by all stakeholders involved. Several areas for improvement across the industry were identified: including the wider implementation of automation, a heightened focus on environmentally conscious design methodologies, and an increased tendency among individual companies to research, analyze current areas of improvement, and foster innovation.

While sustainability is an ever-evolving concept, the study successfully established certain metrics for environmental, social, and economic sustainability within the fish processing sector, outlining sustainable guidelines - in correspondence to the introduced Sustainability by Design-approach. However, it is repeatedly crucial to note that these findings were based on responses from a single participant, and it is preferable to expand the utilization of the SDAG tool in collaboration with multiple stakeholders. Particularly, in the in-depth study, it was recommended that the tool should be employed in conjunction with a process equipment manufacturer, as they possess the ability to facilitate the implementation of sustainability measures. This was also highlighted in section 2.2, as the manufacturer is a stakeholder that can set constraints as well as identify localities of advancements. By identifying areas for improvement in the design of existing physical equipment, this collaboration would enable the establishment of more concrete design criteria.

The SDAG tool operates by initially identifying its primary focus, which centers around a specific FPE extensively utilized in Atlantic Salmon processing industry. Its purpose is to be applied to conventional food processing equipment to develop a blueprint for designing sustainable new FPEs. The primary objective is to implement the new technology of SGS in the processing line, with specific attention given to the left processing line depicted in Figure 5.2.1, particularly within the filleting department of the fish processing factory, where the SGS could potentially be integrated. An example of such a filleting department layout is illustrated in Figure 4.2.1. The SGS FPE would be the next process in this line, directly before the packaging step.

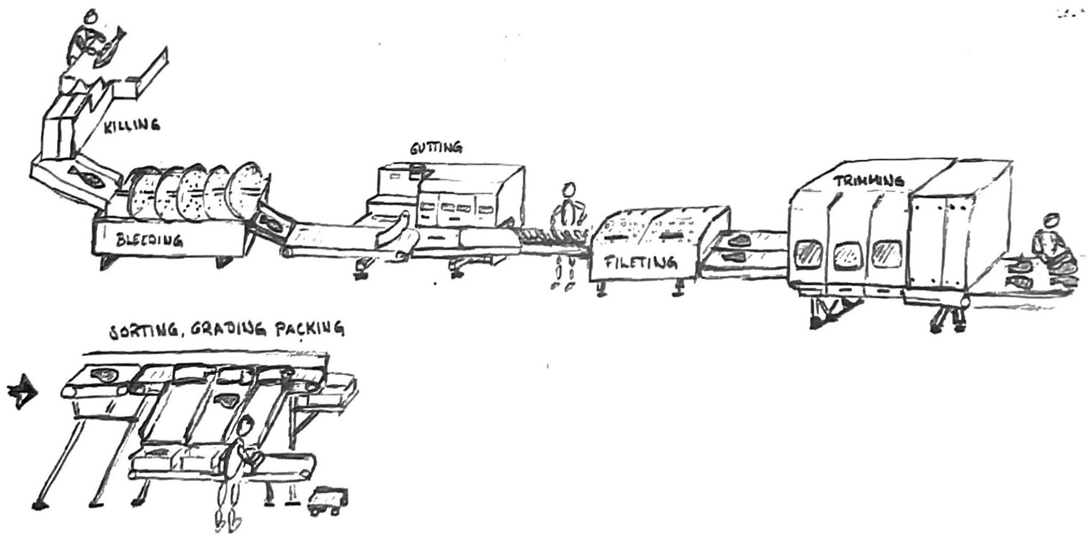

Figure 4.2.1: An example of a layout of fish processing operations in line. The layout drawing was created by Bar [32].

During the visit to the processing company, it was determined that the focus would be on the processing equipment with the most potential for improvement within the specific factory, which happened to be the trimming machine. The automatic trimming machine performs tasks such as calculating an optimal cutting pattern, evaluating each fillet, providing grading information, and sorting fillets into different further processes [110]. When visiting the FPE manufacturer, the assessment tool was used slightly differently, assimilating similar information but with an emphasis on weighing the objectives in relation to the development of a potential new processing equipment. Rather than evaluating one specific existing FPE, the evaluation rooted in multiple FPEs and the idea of a perfect one. Some modifications were made to the tool, including the addition of objectives specific to the manufacturer and the removal of objectives relevant only to the processor.

One of the dimensions of the SDAG tool, namely the economic dimension, is presented in Figure 4.2.2 as an example. It enumerates all the relevant objectives within that dimension on the left side. The objective of the tool is to determine the importance of each objective for the company, explain the rationale behind its importance, assess the extent to which the company fulfills the objective, identify actions taken to fulfill the objective, and propose potential directions for further improvement. To capture this information, a survey was designed to simplify the process as the original SDAG tool was deemed too complex to administer directly. After obtaining consent, participants received the straightforward survey listing all the objectives. They were asked to prioritize each objective by indicating its level of importance for the company and assess the company's current level of achievement for each objective as a percentage. Before completing the survey, participants were provided with an informative page explaining how to weigh the objectives and interpret the assessment. The importance weighing [34] and assessment percentage weighing [111] methods used in the survey were derived from the original SDAG tool developed by Claude Villeneuve, Olivier Riffon, and David Tremblay. The processor who looked specifically at the trimming machine, ended up evaluated a set of categorized, sustainable objectives aimed at trimming machine, where each objective aimed to enhance the sustainability of the product or the company.

ECONOMIC DIMENSION: Seeks to address the material needs and financial empowerment of individuals and communities.							
Themes	Goals	Weighting	Justification for weighting	Assessment	Actions planned or already implemented	Opportunities for improvement	Priority
1	Responsible production						
1.1	Producing quality goods and services						
1.2	Ensure a time-efficient processing						
1.3	Ensure adequation between needs and the goods and services produced						
1.4	Promoting eco design from a product life cycle perspective						
1.5	Promote sustainable industrialization						
1.6	Implement extended producer responsibility						
	Average weighting : Responsible production	0,0	Weighted performance : Responsible production	0 %			
2	Economic viability						
2.1	To ensure economic viability						
2.2	To ensure a minimum additional capital and operation cost						
2.3	To ensure a high profit margin						
2.4	To limit the financial risks						
2.5	To limit the return on capital						
	Average weighting : Economic viability	0,0	Weighted performance : Economic viability	0 %			
3	Work						
3.1	To enhance job creation						
	Average weighting : Work	0,0	Weighted performance : Work	0 %			
4	Energy						
4.1	To reduce energy consumption						
4.2	To plan a wise use of energy						
	Average weighting : Energy	0,0	Weighted performance : Énergie	0 %			

Figure 4.2.2: The economic dimension of the SDAG-tool.

As said, the participant assessed the extent to which they believed each specific objective had been achieved; specifically, using a scale from 1 to 3, where 1 indicated a desirable objective, 2 represented an important objective, and 3 denoted an indispensable objective. To indicate the current (or potential, in the case of the manufacturer) level of fulfillment for each objective, the participant assigned percentage points from 0-100%. A comprehensive explanation of the assessment scale etc. can be found in the study titled *"A Systemic Tool to Consider Sustainability Issues in the Design Step Towards a More Sustainable Food Processing Equipment"* by Esmaeilian [36].

4.2.2 Results from the Processor

The full filled out SDAG tool from the assessment with the processor is added in Appendix A. In addition, the resulting graphs are shown in Figure 4.2.3. Here, the aim is to summarize these results to later point at the biggest differences between the processors and manufacturers viewpoints. Comprehensive comments on the results can be found in the in-depth study [2].

Through the first tool assessment, it was also established that the results provided specifically objectives that either demand something from the processing or manufacturing company themselves, as well as demands for the actual product development. This created a list of *objectives for the stakeholder* in terms of many

Project :	Sustainability in trimming machine	
Date :	15. Oct 2022	
DIMENSION	Average weighting	Average performance
SOCIAL	2,6	87 %
ENVIRONMENT	1,8	80 %
ECONOMIC	2,7	90 %
FUTURE CONSIDERATION	2,9	79 %

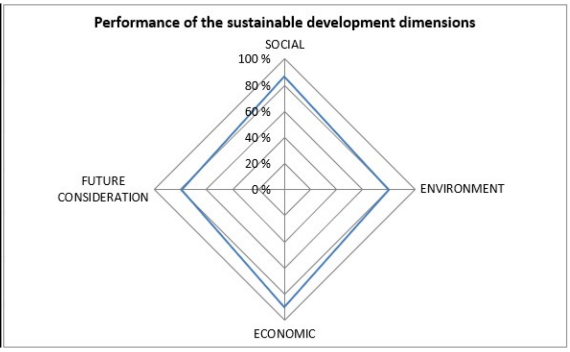

Figure 4.2.3: The overall results from SDAG assessment with the processor.

social and economic aspects, as well as a more clear list of *objectives for what to include when implementing sustainability in NPD.*

In general, the results from the SDAG tool initially showed that the industry is seeking perfection through innovation, adaption of future trends and continuous improvements, and that the industry currently is in a transition where the environmental concerns and issues are seen as a value in the same way as worker safety or sales prices. This was also underlined in subsection 3.3.2, emphasizing the increasing relevance of Design for Environment. The summarized key takeaways from each dimension of the processors SDAG tool assessment are as follows: Environmental Dimension:

- Compliance with regulations and active participation in their creation
- Minimization of resources such as energy, food-grade water, and cleaning agents
- Control and reduction of all forms of outputs (noise, odor, effluents, waste)
- Avoidance and/or compensation of greenhouse gasses (GHGs) and atmospheric emissions

Social Dimension:

- Ensuring food safety and security through control tests, hygiene training, and adherence to regulations
- Providing a healthy and safe working environment, including a high-quality canteen and good ergonomics
- Offering basic training, education, and Health-, safety- and environment-courses (HSE).
- Designing equipment that is easy to use and ensure a secure work environment

Economic Dimension:

- Responsible and time-efficient processing of quality goods using automation and high-technology equipment

- Ensuring economic viability through proper project analysis, maintaining a high profit margin, and clear financial planning
- Promoting job creation and staying up-to-date with industrial trends to attract job seekers
- Reducing energy consumption through automation and efficient processes

Future Consideration Dimension:

- Pursuing sustainable innovation through research and development, collaboration with manufacturers, and smart automation
- Assessing and managing risks at all levels, promoting resilience and crisis management training for managers
- Digitalizing data for effective monitoring and traceability throughout the fish processing lifecycle

4.2.3 Results from the Manufacturer

As with the processor, the full SDAG tool filled by the manufacturer, is shown in the Appendix, Appendix B. The resulting overall spiderplot is shown in Figure 4.2.4.

Project :	Sustainability in trimming machine	
Date :	03. May 2022	
DIMENSION	Average weighting	Average performance
SOCIAL	2,8	88 %
ENVIRONMENT	2,5	76 %
ECONOMIC	2,2	74 %
FUTURE CONSIDERATION	2,4	87 %

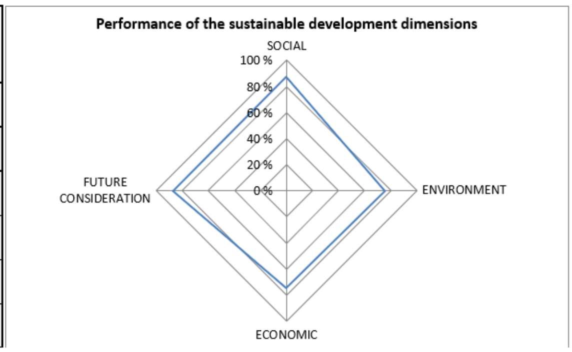

Figure 4.2.4: The overall results from SDAG assessment with the manufacturer.

As discussed earlier, the assessment results from the manufacturer reveal that many of the general objectives receive similar ratings as for the processor. Moreover, comparing specific objectives becomes a little challenging due to the differences in the assessment approaches. However, particular attention is given to areas where the two stakeholders exhibit complete agreement or disagreement, as these instances provide valuable insights for determining the most effective design criteria using the SDAG tool. Without delving into the detailed results of each dimension, the focal point lies in identifying the most noteworthy surprises or unexpected findings in relation to other objectives or the perspective of the other stakeholder. The following presents a summary of the key takeaways from the manufacturer's assessment using the SDAG tool for each dimension:

4.2.3.1 Environment Dimension

ENVIRONMENT DIMENSION		
THEME	Average weighting	Average performance
Ecosystems	3,0	90 %
Resources	2,6	68 %
Climate change	2,0	90 %

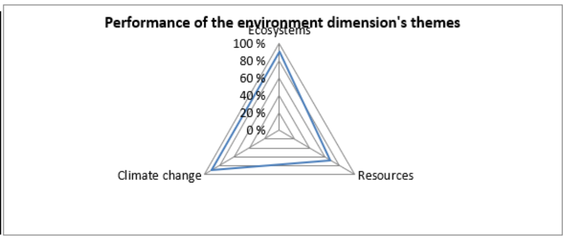

Figure 4.2.5: Spiderplot of manufacturer results in the environment dimension.

The environment dimension scores an average performance of 76% overall, quite similar to the 80% of the processor. However, as opposed to the processor, the weighting is high as well. "Ecosystems" is a high priority because the manufacturer follows all required standards and regulations. When it comes to yield losses, they occur at the processing facility, not necessarily because of the manufacturer - their job is only to design an equipment that doesn't allow for fillets to fall down - which is a main priority.

2	Resources						
2,1	Minimize energy consumption	2	According to the manufacturer, energy usage is never a priority of the client. Energy will be one of the things the clients consume the most as they have a large, automated, generally high tech. factory. It is somewhat conisdered by this specific manufacturer, but the electricity spent is only considered "a drop in the ocean" as part of the entire industry.	60	Improvement potential of maybe 10% electricty saved for engines in the factory, maybe 20 kW	Prioritize energy usage to a higher degree	Maintain
2,2	Minimize food grade water consumption	2	Depends very much on the client, because some pay a lot for water, while others not	60	None really, as it is customer-dependant. For the clients that want to minimize water usage, it is prioritized, for others, not so much	Always prioritize minimization of water consumption	Maintain

Figure 4.2.6: Two objectives of the resources theme.

For the "Resources" theme, there are many similarities to the processor, with the manufacturer only having a slightly higher evaluation rating. Noticeable is that the two first objectives of energy and food grade water consumption are highly prioritized by the processor, yet not by the manufacturer (Figure 4.2.6). The processor suggested improvement areas in reducing power and lightning during off-times and using distilled sea water as production freshwater. On the other hand, the manufacturer claims that energy usage is never a priority of the client. Energy will be one of the things the clients consume the most as they have a large, automated, generally high tech. factory, but the electricity spent by one equipment is often considered only a drop in the ocean as part of the entire industry. When it comes to food grade water consumption, the evaluation is again low due to the customer dependency. While the processor in this study prioritizes it, there are local variations in costs of water and therefor it is not always prioritized fully. For both the processor and the manufacturer, most of the other objectives score generally well. The processor claimed that the objectives related to design for cleanability, reduction of high-impact resources and material usage in construction are deemed to be more relevant for the manufacturer and hard to evaluate correctly from their standpoint. According to the manufacturer, the improvement potential here lies in supplementary collaboration between the company and their manufacturer, as well as added material research and product development. These objectives have mostly proven to be highly prioritized and evaluated. A stand out objective is however "choosing low-impact materials", but it is dependant on the size of the manufacturing company: as the specific manufacturer in this study has a low variance in materials, and does no particular analyses on the impacts of the ones chosen.

The low weighting in the climate change theme is almost indistinguishable to the answers given by the processor. The processing and manufacturing parts of the fish industry consider the climate change objectives as irrelevant, with both participants believing this irrelevance stems from the companies' lack of GHG emissions; eliminating the need to quantify, compensate for, or plan for adaptation measures regarding climate change. It is worth noting that while aquaculture contributes to GHG emissions similar to sheep production, the emissions from this aspect of production are minimal, mainly stemming from fish farming, and not the processing facilities [112]. The objective with a weighting of 2, "reduce atmospheric emissions," is primarily relevant to the company's transportation emissions, which can be improved through electrification. However, it is not necessarily up to the fish industry alone to make a change when it comes to transport electrification, as not all transport related to the processing factories is owned by the company.

The theme "Output" from the original SDAG tool has been removed for the manufacturers assessment as it is only dependant on the processor.

4.2.3.2 Social Dimension

SOCIAL DIMENSION		
THEME	Average weighting	Average performance
Food	3,0	100 %
Health	2,7	81 %
Safety	3,0	100 %
User-friendly	2,5	72 %
Work environment	3,0	80 %

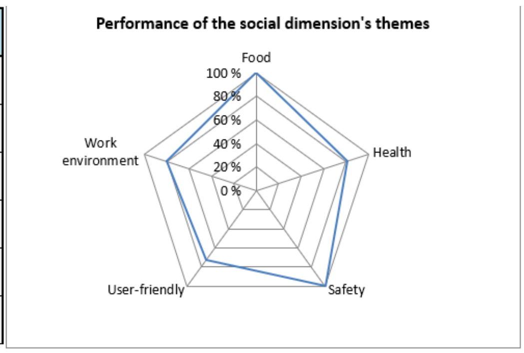

Figure 4.2.7: Spider-plot of manufacturer results in the social dimension.

Figure 4.2.7 shows that the social dimension has both high priority weighting and high performance assessment results, for the manufacturer the same way as the processor. Again, since, fish industry is part of food industry, the theme "food" is highly prioritized, and there is a lot of pressure and focus on food safety and security in Norwegian food industry [113]. Because of basic training in hygiene and safety, a strong focus on cleaning and avoiding bacteria growth, and specific food safety demands from the clients, these objectives also score well. Likewise as for the processor, the same applies to "Safety" and "Work Environment", both weighted highly due to prioritization of workers safety and comfort, keeping a clean and updated environment according to Norwegian company standards.

The "User-friendly" theme (previously known as "education") is the lowest weighted and lowest scoring theme. The main reason is that it only consist of two objectives, of which one is rated and evaluated lower, namely the ensuring

4	User-friendly						
4,1	Ensure an easy to work equipment	3	Like cleanability, durability, and other simplifying, it is important that the eqipment is easy to utilize for the potential factory workers	80	None specific, design for accessibility is prioritized, but it is not always simple to fullfill	Always room for simplifying further, or reducing risk of defects that can create hard tasks for caretakers	Maintain
4,2	Ensure a noncomplicated design process for manufacturing the equipment	2	Simplifying the manufacturing saves time, material, etc.	60	The design process of most equipments are simply not "noncomplicated" because they are advanced.	No further comments	Maintain

Figure 4.2.8: The objectives of the user-friendly theme.

of a non-complicated design process for manufacturing the equipment. This separates the processor and the manufacturer as the processor was unable to give an opinion on the manufacturing process. However, now it is clear that the level of difficulty of designing is rarely prioritized. This mainly roots in the fact that the processing equipment are advanced technical machines, perhaps even tailor-made, and therefor the prioritization of having a non-complicated process cannot be made. If an equipment works and has a positive effect on the quality of the product, there are other objectives that need to be less prioritized, and therefor it would be worth having a complicated design process, or even a slightly more "difficult-to-use" equipment.

2	Health						
2,1	Provide an ergonomic condition for employees	3	For the workers that utilize the equipment, the work can be physically exhausting or demanding, so ergonomics are very important	100	All design is done to ease work for employees of the factory. All parts of design are accessible, easy to clean, easy to dismantle, easy to learn, easy to use, etc.	Not considered	Maintain
2,2	Consider gender status in ergonomic design	2	Ergonomic design in terms of gender status because all products are universal for both genders.	50	The manufacturer doesn't really design anything that needs gender status considerations	Keep in mind that the manufa	#VERDI!
2,3	Reduce task duration	3	It is natural that the process has tasks that can take a long time	100	Manufacturer has little comments on this and assesses the 100% to an ideal product, not a specific one. Not all processes are autonomous yet, and have improvement areas in adding automation - thereby reducing task duration	There are possibilites for automating all potential processesing equipments made	Maintain
2,4	Reduce task repetition	3	It is natural that things are constantly repeated in fish-factories	100	If processing equipment are made automative so that there is repetitiveness for manual workers, they are perfect. A co-bot could also be added to some processes, to reduce repetitiveness. Remember, the assessment here is for an ideal equipment	Not considered	Maintain
2,5	Reduce susceptibility to pollutions from machinery waste products	2	Not considered relevant, as no equipment really has pollution	50	The low assessment rating is given because it is not considered relevant. If they were to produce machines that produce pollutions, it would absolutely be prioritized, so keep in mind the assessment rating can be deceptive.	Making equipment require even less human attention and interaction if possible	Act
2,6	Reduce task difficulity in the sence of required force	3	Not really relevant as most of the manual work requires little physical force, apart from maybe some operational work done by caretakers.	100	The trimming process is automated, but can require physical work if it potentially breaks down	Further reduce risk of machine defects	Maintain
2,9	Reduce any other irritants	3	All aspects of workers health and environment are generally important. Specifically, noise pollution can affect physical health.	80	For all things considering "health": There is always room for improvement with better solutions. Can add even more automation, reducing lifting and moving of fish. The more machines you have the less work afterwards. Manufacturer specifically aims to reduce noise irritants because these are considered the most relevant health issues	Reduce all noise emissions to acceptable levels that are not affecting workers health. Also prioritize other possible irritants.	Maintain

Figure 4.2.9: The objectives of the health theme.

Looking at the objectives in "health", two of them stand out. Like for the processor, consideration of gender status has no prioritization, relevance or need for a change, as most tool and interior are unisex. Another objective that stands out according to the manufacturer, opposing the processor, is "reducing the susceptibility to pollution from machinery waste products". This is a non-prioritized and less evaluated objective because the manufacturer deems it as irrelevant, stating that *"there are no machines here that produce pollution"*. If there were, it would be prioritized, so the actual assessment is somewhat deceptive. Apart from that, all other objectives have a weighting of 3 and also have a performance of 80% and higher, most even 100%. Some reasons for the company's high performance assessment here include the providing of a healthy environment, a high-quality canteen, good general ergonomics, health services, variability of work and reduced duration of work - completely in line with the processors answers and listed take-aways. For all these objectives it is said that there is always room for improvement with better solutions, for instance by adding even more automation that e.g. could reduce possible heavy lifts. The more machines you have the less work afterwards. The manufacturer specifically wishes to reduce noise irritants because these are considered the most relevant possible causes of health issues. Repetitiveness is said to not be a problem, as the most repetitive actions are automated, and there is simply less repetitiveness for the manufacturer than for the workers in the processing facility. Again, some processes simply rely on manual work due to their demanded precision and current lack of perfectly specialized technology in those specific areas.

As was highlighted in the in-depth study, the high percentage points given to "creating a feeling of security" within the safety theme is possibly somewhat deceptive. This objective also considers job security. Given the introduction of the "salmon tax" and the consequent number of lay-off notices sent out to employees of fish processing facilities (subsection 1.5.2, there is already some indication that governmental decisions puts doubt to the assessed 100% feeling of security.

4.2.3.3 Economic Dimension

ECONOMICAL DIMENSION		
THEME	Average weighting	Average performance
Responsible production	2,3	100 %
Work	2,0	75 %
Energy	2,0	70 %

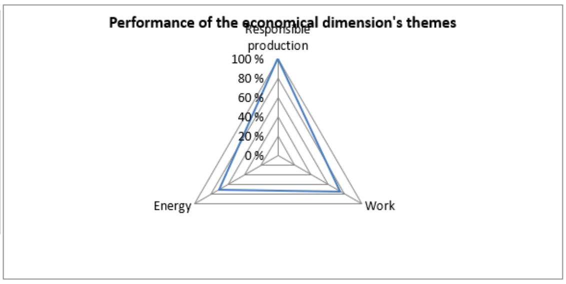

Figure 4.2.10: Spiderplot of manufacturer results in the economic dimension.

While the best results for the processor came in the economic dimension, the same cannot be said for the manufacturer, neither for the weighting nor the performance evaluation. However, for the "responsible production"-theme, the performance is 100%. The processor is all about producing quality goods and ensuring time-efficient and sustainable production, and so is the manufacturer. However the weighting is slightly less, simply because the specific manufacturing company is quite small, and their production is based on the demands from multiple clients. While the processor is controlling the market as a larger company; producing continuously efficient in-line products at any hour of the day, the manufacturer works more on-demand of clients and creates their products with added planning and more processes. However, the quality, time efficiency and controls like LCA are extremely important for both, therefor underlining the 100% assessment score. Like for the processor, there will always exist some improvement potential in including even more automation or high-technology equipment to add efficiency. This also applies to the previous "economic viability" theme, where the results are so good that there is no comment or idea on how to improve, apart from continuing the good work and avoiding too high financial risks. This theme has been removed from this assessment as the objectives are more aimed at the processor.

A deep dive in the "responsible production" theme was done, as the average performance score was specifically interesting. Therefor, the manufacturer was asked to prioritize the objectives relative to eachother based on customer demands:

1. Producing quality goods (1.1): The highest prioritized objective. Ensuring the production of high-quality products using the right standards and food-grade materials is essentially what the industry does.

2. Continuous line processing and time-effectiveness (1.2) (1.3): are related and considered together. Having a continuous line process ensures efficient processing, which is important for meeting customer demands and avoiding waste.

3. Promotion of Sustainable Industrialization (1.7) is highly prioritized and gaining importance. While currently more theoretical, it is becoming increasingly requested by customers. In the future it might be on top of the prioritization list, but currently it is on par with the next two objectives:

4. Correspondence between demand and production in terms of quality and quantity (1.5): Balancing quality and quantity is a critical aspect of meeting customer requirements. At the same time maintenance ease (1.4) is absolutely important, and is frequently asked for by customers wanting a significant advantage.

5. Environmental impacts (1.6) is the least prioritized objective, because environmental impacts are usually not a significant concern in the industry, given that product often are not environmentally unfriendly, has sizeable consumption or any emissions.

When it comes to "work", the only objective is to enhance job creation, which has some room for improvement, but is not indispensably prioritized. The company's work in society and elsewhere creates no need to advertise jobs further, as the company is smaller and local. The last theme within the economic dimension is "energy", which looks at energy usage from an economic point of view instead of the previous environmental viewpoint.

4	Energy						
4.1	To reduce energy consumption and the respective cost	2	Somewhat answered in the environment aspect, not considered further	70	See environment aspect	Not relevant	Maintain
4.2	To plan a wise use of energy	2	Keeping the energy usage to a degree where it wont affect the company in a negative way econominically is very important, but the manufacturer has not considered this themselves because they are very rarely asked by their clients to consider energy usage. For the manufacturing company themselves, they have only some improvement areas in reducing energy usage, so it is not prioritized	70	The company spends energy in a wise way with its simply and quick parallell processes.	There is probably room for improvement in reducing energy usage by turning off lights or machines when not in use or the short periods inbetween shifts. It is unknown what the manufacturer things of this, or what the shifts are like at the manufacturing company.	Maintain

Figure 4.2.11: The objectives of the energy theme in the economic dimension.

Within "energy", the biggest differences between the manufacturer and processor can be seen. While the processor prioritized energy consumption and performs well using automation, quick processes and assembly lines, it is not prioritized as much by the manufacturer. Of course, keeping the energy usage to a degree where it wont affect the company in a negative way economically is very important, but the manufacturer has not considered energy usage of each manufactured product themselves because they are very rarely asked by their clients to do so. The manufacturer, as a company, only have some improvement areas in reducing energy usage, e.g. by turning off lights or machines when not in use or during periods in between shifts. According to the manufacturer, energy usage is client dependant, and a minimization of energy in a new developed product tends to be a rare demand when the overall energy usage of the industry itself is so high.

4.2.3.4 Future Considerations Dimension

FUTURE CONSIDERATION DIMENSION		
THEME	Average weighting	Average performance
Innovation	2,4	100 %
Risk management and resilience	2,5	80 %
Data digitalization	2,0	50 %

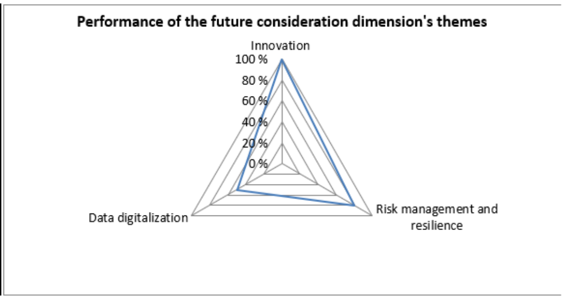

Figure 4.2.12: Spiderplot of manufacturer results in the futureproof dimension.

From previous objectives' assessment and specifically the "innovation" theme, it is clear that both the processors' and manufacturers' company seeks to innovate and be the best in its industry - as most do. The manufacturer tries to do so through implementing full automation throughout the production line and constantly optimize based on customer needs. The manufacturer has given an average performance weighting of 100%, which is somewhat deceptive, knowing that there are improvement areas in terms of further participation in studies, research and development, market testing, as well as further collaboration with other stakeholders and optimizations of processes. More automation can add efficiency and could improve other dimensions as well, as done by the processor. The performance rating is rather an evaluation of what should be given to an ideal product. Looking at the weighting within the "innovation" theme, most objectives are weighted indispensable, but noticeably, the objectives regarding "future trends", "adaption of robotic washing function", and "innovation potential" are weighted less. This is mainly due to the manufacturer company not having the possibility to always keep up to date on the trends and innovation potentials of the industry, as they are not extensive enough. While a robotic cleaning function would be great for any equipment made in the factory, the investment can also become too large. Another objective weighted only desirable is regarding the equipment versatility, yet again because the equipment made by the manufacturer are tailor-made and can therefor only have one specific processing method, not multiple. There are surely possibilities for combinations, but these are not requested, too costly and too complicated in this case.

The objectives within innovation are regarded extra important when developing a new product, and are therefor investigated a little further. Based on the manufacturer's perspective, the objectives within innovation can be summarized and prioritized as follows:

1. Efficiency (1.3) is the most prioritized; and automation is critical for increasing effectiveness and meeting customer needs for productivity while ensuring delicate treatment of the products.

2. Continuity (1.6) is considered very important, almost on par with efficiency. Optimizing cooperation, identifying and solving bottlenecks and ensuring smooth processes are key for uninterrupted operations.

3. Being adaptable to Industry 4.0, IoT, Smart process control, machine learning, etc. (1.8) can improve efficiency, increase production, reduce costs, and will lead to the company staying up to date with future trends and innovation. A must for a high tech. company nowadays.

4. Innovation (1.1) and Research and Development (1.2) are considered together and given a relatively high priority. Both objectives are important for maintaining an innovative design and constantly improving products. Keeping up to date with future trends (1.7) comes in at the same prioritization level, as incorporating future trends in product design is important for remaining competitive.

5. Versatility (1.5): The industry focuses on specialized products rather than universal applicability so it is not prioritized.

6. Whilst being very attractive, robotic washing (1.4) is the least prioritized objective. Other challenges need to be addressed before considering robotic washing as relevant.

Although the weightings and average performance can be hard to interpret, some of the largest differences from the processor can be found in the manufacturers answers withing both "risk management and resilience" and "data digitalization". This is again very much dependant on the fact that the two companies are different sizes and work with different products, but it can give a somewhat holistic view on the different viewpoints to overall sustainability. While the processor significantly prioritizes risk management through identifying, evaluating and mitigating risks to avoid malfunctions, rework and unnecessary costs, the manufacturer admits they only somewhat analyze and assess the risks on each level, but not thoroughly enough. While both are good at resilience, detecting failures and being adaptable, the manufacturer does not have the same standards (apart from HAZOP) and regulations in risk management.

Looking further into risks in terms of standards and regulations, standards were also given high assessment scores within the "food" and "safety" themes in the social dimension. Therefor, the manufacturer was asked for more information on standards: Standards and regulations are not typically asked for when customers approach them. Instead, for a manufacturer of this size, standards come into play after clients have made initial contact. Different clients have varying standards based on their size and industry focus.

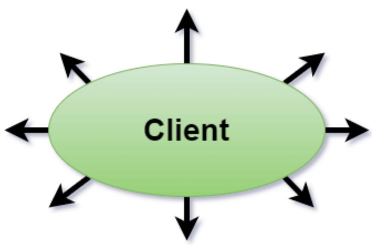

Figure 4.2.14: It is undeniable that the manufacturer is client-dependant and oriented.

Smaller companies may require simpler plans or equipment to be market competitive, while larger fish-slaughterhouses have more specific and stringent demands. Choosing the right standards can be

2	Risk management and resilience						
2.1	To identify risks at different operation levels	2	Obviously it is important to know what risks are involved in all processes and part of the processes	50	A lot of improvement potential. According to the manufacturer, the risks are not identified a lot, "sometimes we just throw on a sticker". Risks are somwhat analyzed and assessed on every level already, but not thouroughly.	Can improve a lot since most projects have high risks	Act
2.2	To manage risks associated with new technologies	2	The company are willing to be, and have been taking risks. However, risks are not assesses thoroughly	50	No further comments apart from those in 2.1.	Little ways of improving this goal in terms of new projects, because risks are always involved even though an analysis can be made to identify them beforehand, they need to be physically tested. However, it is important that these risk analyses are actually done correctly.	Act
2.3	To apply the principle of prevention	2	It is important to use principle of prevention to avoid problems	50	Risk is somewhat assessed within the factory (HAZOP), but again, not good enough.	No further comments	Act
2.4	To have ease in controlling in case of FPE failure	3	It is easy to identify FPE failures	100	When equipment fails, the area that leads to failure is simple to identify by seeing what failure has occured	Not relevant	Maintain
2.5	To promote an equitable distribution of risks	3	It has to be clear who takes the blame when the company is involved in "risky business" with multiple stakeholders	100	There is a collaboration between the company and exporters on who will take the risks. If the company takes part in projects where new things are tested, it is identified and distributed fairly who will take the potential risks.	The manufacturer says there are little projects where the risks involved are so large that this is relevant	Maintain
2.6	To provide planning actions and consideration for adaptions to global changes	3	The company is keen to follow trends at any time, also the trend of global changes, like climate. We are business cycle/conjuncture controlled and adaptable, "we align ourselves with the fishing fleet".	100	Something that is done constantly on all levels	No further comments	Maintain

Figure 4.2.13: The objectives of the risk management and resilience theme.

challenging for the manufacturer, as client requirements may change over time. They often have to present options to clients and let them make the final choice. Cleanability is a crucial consideration, especially for salmon processors dealing with potential issues like Listeria bacteria [114]. Material choices at the company adhere to standards and regulations, with the use of stainless steel (SAE304 or SAE316), food-grade fats and water, and certified plastics. They prioritize sourcing plastics from trusted suppliers and avoid using potentially toxic materials that may be present in recycled or uncertified plastics from unreliable sources. This underlines high prioritization when it comes to standards within material choices, as well as the standards of food safety, hygiene and safe work environments.

When it comes to data digitalization, there is a wish to be able to monitor the products digitally like the processor manages to do, but there is little control through data digitalization currently. While fish fillets demand many control tests, it is not prioritized the same way for the equipment that handle the fillets, and the manufacturing company simply does not have the capacity either.

4.2.3.5 Conclusion of Manufacturer Results

Summing up the results from using the SDAG tool in collaboration with the manufacturer, most of the results are similar to the processors results. This can be interpreted positive, given the fact that the two stakeholders are not related in any way and have not reached conclusions influenced by each other. However, there are some differences from the processor.

While most of the objectives score likewise within the environment dimension, there is a big difference in the prioritization of energy usage. While the processor claims that energy usage is a high priority, the manufacturer states that reduction of energy is rarely asked for, as the consumption of one FPE often is negligible in the bigger picture. The same counts for food grade water consumption, as not all the manufacturers clients have the ability or need to prioritize minimization of water. On the other hand, the manufacturer puts a little more focus on design for cleanability and using as little as possible materials and resources.

Looking at the social dimension, the prioritization is very much alike, as there is a concentrated focus on food quality, safety, security, health and work environment throughout the food industry. A noticeable addition from the manufacturer to the social dimension is the fact that the difficulty of the design process is rarely considered, given that most equipment are advanced and "worth" a complicated design process. While most of the objectives in the social dimension are alike, there are some natural differences coming from the fact that the two facilities produce different products. In general, the improvement areas are within the addition of automation and further reduction of irritants - in specific; noise emissions for the manufacturer.

The processor excels in economic viability, producing efficient products continuously and avoiding financial risks. The manufacturer does the same, but being a smaller company, focuses and relies more on meeting client demands and planning the production processes. For both stakeholders, efficiency and continuity are the main parameters, but the manufacturer also places high importance on promotion of sustainable industrialization, as well as maintenance ease and correspondence between demands and production. Environmental impacts are the least prioritizes objective for both the processor and the manufacturer, as they are typically not a significant concern in the industry. Looking at the energy theme within the economic dimension, the processor prioritizes energy consumption a bit more than the manufacturer. Although both focus on utilizing automation, quick processes, and assembly lines and have the same improvement areas in their own facilities' energy consumption (turning of lights and machines when not in use), the manufacturer is seemingly rarely asked by clients to consider the actual energy consumption of each FPE designed.

Both the processor and the manufacturer strive for innovation and excellence in their industry. The manufacturer focuses on implementing full automation and optimizing processes based on customer needs. However, there are improvement areas in terms of research and development, market testing, collaboration with other stakeholders, and exploring further innovation potentials. The same counts for the processor, even though it pays off to be a larger company, and the improvement areas are smaller. Notably from the future considerations dimension is that equipment versatility is not prioritized, but only because the manufacturer specializes in tailor-made products with specific processing methods. When it comes to risk management and resilience, the manufacturer acknowledges analyzing and assessing risks, but not comprehensively like the processor. They have different standards and regulations in risk management compared to the processor, often made after clients have made initial contact. In terms of data digitalization the processor excels and utilizes it to monitor effectively, while the manufacturer has, and needs, less controls and monitoring. The main reasons for the differences within data digitalization are due to the lack of capacity, but since the wish for improvement is there, these objectives should not be considered as disagreements or divergences.

4.2.4 Combining the Design Criteria

The study aims to highlight the need for easily implementable design guidelines that provide environmental guidance throughout the fish food value chain. Some of these guidelines were presented as company-oriented objectives in the in-depth study [2]. The subsequent paragraphs aim to specify the design requirements for the machinery itself, outlining the features that industrial food processing equipment must incorporate to achieve sustainability. Remember that these are an addition to adhering to the company-oriented points. The design criteria serve as goals for integrating sustainability into the initial design of production lines and can be used to evaluate new product designs. They also serve as a tool for managers to assess the potential for sustainable success and alignment with their company's goals. The design criteria are categorized into primary and secondary criteria, with the former being crucial for a successful project and the latter representing desirable but non-essential features. Balancing these criteria may require trade-offs, as implementing one criterion may make another infeasible or costly. However, striving to fulfill both primary and secondary objectives is ideal for achieving comprehensive sustainability implementation and optimization.

The design criteria were created in the in-depth study before the manufacturer was included. The initial list of design criteria consisted of the following:

The preliminary design of soluble gas stabilization (SGS) must include the following features in order to be as sustainable as possible:

- A continuous, electrified and automated process with minimal yield loss of food, minimal energy usage, minimal noise and waste emissions.
- A design that ensures food quality, security and safety, is easy, harmless and comfortable to use and learn.
- A design that fits into the assembly line, and enhances a wise use of energy that ensures time-efficient processing of quality products guaranteeing economic viability.
- An innovative, smart design, with digital information data that is easy to monitor, and has little risks of sincere defects or disruptions.

Secondary, desirable features:

- A design that ensures optimal utilization of rest raw material for consumption.
- A design for easy cleanability and a reduced need for washing agents
- A design that promotes eco design, demands prudent use of resources, time and material as well as non-complicated manufacturing

Based on the differences identified between the processor and the manufacturer in terms of their prioritization and objectives in Section 4.2.3.5, the design criteria for the soluble gas stabilization (SGS) preliminary design should be modified, but only a little. Mainly, cleanability ease can be moved upwards to a primary criteria, as it will have a large effect on resource usage, and is prioritized for producing quality products. Energy consumption in terms of the actual FPE is not considered relevant by the manufacturer, but the energy usage optimization in its entirety is still important, so can therefor stay as part of a primary objective. Even though the manufacturer had no strong focus on making an equipment easy and comfortable to use and learn, it is still part of an overall health, safety and work environment optimization, so can still be included as a primary objective. When it comes to data monitoring, there were differences, but there is a general strong wish for implementation and innovation within the relevant themes, meaning this objective can also stay as a primary design criteria.

By incorporating the modifications, the design criteria reflect the perspectives of both the processor and the manufacturer, ensuring a comprehensive and balanced approach to achieving sustainability on the way towards a preliminary design of the SGS equipment. To summarize, when adding the changes made to align the design criteria with the manufacturer's perspective, this becomes the final list of design criteria:

Primary design criteria:

1. Implement a continuous, electrified, and automated process that minimizes yield loss of food and optimizes production efficiency

2. Ensure food quality, security, and safety, while considering the ease of use and learning for operators

3. Design for cleanability, reducing the need for washing agents and promoting eco-friendly practices

4. Create a design that integrates seamlessly into the assembly line, optimizing energy usage and ensuring time-efficient processing of high-quality products for economic viability

5. Incorporate digital information and data monitoring capabilities to enhance operational control and minimize risks of defects or disruptions.

Secondary, desirable features:

1. Explore opportunities for optimal utilization of rest raw materials to minimize waste

2. Promote eco-design principles by minimizing the use of resources, time, and materials, while simplifying the manufacturing process

In Figure 4.2.15-Figure 4.2.18, detailed descriptions of each design criterion is provided, specifically tailored for developing a physical design for the Soluble Gas Stabilization (SGS) technology. The existing design criteria address broad areas of improvement, so to enhance their effectiveness, specific approaches to achieve these goals are presented, thereby refining the criteria. Furthermore, an assessment is made to estimate the potential sustainability improvements resulting from the early integration of these design criteria in the initial design phase, demonstrating why to implement the specific objective.

Design Criteria	**HOW** to implement in design of SGS	**WHY** implement in design of SGS
Primary		
Implement a continuous, electrified, and automated process that minimizes yield loss of food and optimizes production efficiency	By evaluating relationships, carrying capacity, removal capacity, etc. in relation to food and ecosytem loss on beforehand. Design the gas chamber in such a way that there are no emissions of CO2. Esmaeilian et al. (2021) concluded that "SGS as a new technology aligns with sustainable goals by enhancing packaging efficiency, reducing distribution costs, lowering amount of plastic materials used for packaging, prolonging food shelf life, decreasing food loss, and opening new opportunities for the related industries". Ergo, there is a lot of potential for sustainability enhancement in this aspect, and the manufacturer must keep this in mind when designing.	All waste must be limited. The factory investigated in this study already claims to only have waste that exits the factory with the rest water (some washing agents, blood, and rest raw material too small to collect). When creating a new part of the production line, the waste must be equally small, or help minimize the existing waste amount. Food grade water reusage and conservation is not considered, as it is not relevant for the SGS concept. Potential escaped CO2 from the SGS technology must be avoided at all times, to maintain the zero GHG emissions in the factory. Through the automation of other processes in the processors facility, it is already proven that a continuous, electrified automation of the process will enhance the minimization of all the aforementioned topics, minimizing yield loss of food.
Ensure food quality, security, and safety, while considering the ease of use and learning for operators	Food quality can be ensured by having a planned location, design of processing equipment and production line. The design should also be simplified to such an extent that it ensures good maintenance, and that educated staff can learn to use the equipment quickly. The design should enhance appropriate waste management, increased productivity, and control potential defects and pests. The design can ensure food security and safety in many of the same ways as in the previous criteria; by ensuring limited food waste, by identifying the consumers food preferences early on and thereafter modify the design of the processing equipment so that it cannot possibly effect the quality (texture, color, etc.) of the food in a way that is different from what is required. Create a clear overview of what effects the processing equipment inflict on its bypassing products. Specifically, the SGS concept should have a closed design that is relatively self-operating, providing a safe work environment.	Food safety is crucial to protect consumers from health risks related to common allergens and foodborn illnesses. Using food preserving methods, food is kept safe by reducing bacterial growth that can cause food poisoning. Having design criteria on food safety and security in the early design phase will provide sustainability through food quality and correspondance between food processing and hygiene, which again ensures the viability and sustainability of food production systems, that resilient agricultural practices are put in place, and an increased productivity and production in order to satisfy the real needs of consumers. The impacts on employees must be as small as possible to also ensure a good working environment and social sustainability. For instance, noise emissions are considered environmental pollution and can have risky health impacts for workers, so must also be minimized.

Figure 4.2.15: Design Criteria 1 and 2.

Design Criteria	**HOW** to implement in design of SGS	**WHY** implement in design of SGS
Primary		
Create a design that integrates seamlessly into the assembly line, optimizing energy usage and ensuring time-efficient processing of high-quality products for economic viability	Specifically, when implementing the SGS in the production line, it is important that it corresponds with the production, therefor is automated, as stated in the first criteria, but also takes into account the number of input and outputs as well as the time it takes to process each product. Evaluations must be made before the design phase to ensure time-efficient processing. The design is constrained by the factory space and efficiency, which also must be evaluated in correspondance with other FPEs. All energy usage must be identifyied and impacts evaluated to minimize consumption, saving money, increasing security and reducing pollution that is emitted from potential non-renewable energy sources: Generally minimize the potential of energy leaks, meaning for instance that the equipment is turned off when not in use. To guarantee economic viability, most actions are company market decisions; but when it comes to the design phase, economic viability can be enhanced through prudent use of both low- and high-cost materials and ensuring efficiency by having an easy-to-learn, easy-to-clean and factory adapted design.	While design criteria 1 focuses on avoiding losses using automation, this criteria focusing on optimization of time-efficient processing while producing quality goods (from the economic dimension). A combined economic criteria and additional environmental criterion. A quality good satisfies the needs for which it was designed in a better and more sustainable way. The longer and more often a product is used to meet a need, the more the impacts of its production on resources and the quality of the environment are justified. If the design is not fitted into the assembly line from early design, time and money can end up being wasted, creating resulting in less economic sustainability. Better energy efficiency and less energy consumption reduces the demand on energy resources and should therefor be prioritized early in the design phase.
Design for cleanability, reducing the need for washin agents and promoting eco-friendly practices	Address strategies for design to minimize the need for cleaning and reduce the costs and impacts of the required cleaning. For instance, the material or design can be chosen such that the cleaning of the equipment requires as little as possible use of agents or equipment.	Cleaning costs can be just as expensive as energy costs. Many cleaning equipments and supplies have significant impact on health and environment, meaning design for better cleanability can minimize these effects. The manufacturer spends a lot of resources in cleanability and prioritizes to minimize the difficulty level of cleaning. It is also somewhat related to maintencance ease, which is prioritzed by most clients.

Figure 4.2.16: Design Criteria 3 and 4.

Design Criteria	HOW to implement in design of SGS	WHY implement in design of SGS
Primary		
Incorporate digital information and data monitoring capabilities to enhance operational control and minimize risks of defects or disruptions	Innovation is stimulated by experimentation and creativity during the design and working as a team to think in terms of multifunctionality. All industries should aim to be innovative in a process and invest in further research and development to create the optimal design. The FPE design can be smart by use of automation, but also by incorporated data monitoring capabilities in line with technological trends like IoT and machine learning. Smart use can be efficient considering capital costs, maintenance requirements, operational costs, job creation, etc. The FPE should be able to communicate with the rest of the factory, and have control tests in correspondance with the other processing equipment. All risks involved in the process must be identified and assessed in a risk scheme beforehand in order to avoid them in all forms. Specifically, the SGS processing equipment must have a design that allows for control, monitoring and testing. Materials must be chosen so that defects or disruptions are avoided as much as possible.	The potential for innovation is a factor that can be decisive for technological change and for better use of resources and human needs, in order to reduce the pressure on existing resources or to use new resources to satisfy human needs. Fostering different actions helps to cope better with changes, to better adapt to changes, therefor risks must be assessed as well. For instance, automation is an innovation that can increase efficiency and relieve workers of some of the stress that comes from repetitive or physcially demanding work. The existence of effective communication mechanisms facilitates the sharing of information and knowledge and helps to make decisions that are more tailored to the needs and context, ensuring great data digitalization.

Figure 4.2.17: Design Criteria 5.

Design Criteria	**HOW** to implement in design of SGS	**WHY** implement in design of SGS
Secondary		
Explore opportunities for optimal utilization of rest raw materials to minimize waste	There are limits to how much raw material can be exploited, so the available raw material must be optimally utilized. Specifically, the design should have established protective regulations, as the amount of rest raw material must be minimized. For instance, in the waypoint before the trimming machine, there are relatively high risks of "floor fish". The waypoint of the trimming machine exists because the trimming machine demands the fish to be oriented in a specific direction; this should not be necessary. Such waypoints must be avoided, or a protective funtion must be added to avoid this fish from becoming waste.	The ecosystems that provide the food supply can be protetected and restored through this, and the ecosystem are a habitat for many species that play vital roles in air quality, the water cycle and climate change, therefor ensuring environmental sustainability.
Promote eco-design principles by minimizing the use of resources, time, and materials, while simplifying the manufacturing process	By focusing on the quality and durability of goods and services produced, and avoid wasting resources in satisfying material needs. By adopting eco efficient approaches, and making good use of sub products in production chains. Some of these actions are already part of aforementioned design criteria, but also take into consideration the actual design process, wishing for the physical manufacturing of the processing equipment to be as simple and little time-, material- and cost-consuming as possible.	Eco design is a practice that reduces the impacts of products on persons and the environment throughout their life cycle, through technical reflection prior to the production cycle. Furthermore, limiting the material and having a prudent use of both renewable and non-renewable resources will create a more environmentally sustainable design.

Figure 4.2.18: Secondary Design Criteria 1 and 2.

4.3 Proposing the Solution Alternatives and Requirements

4.3.1 Initial Ideas

Early in the concept development phase, the ideas that arise are based on inspirational objectives, planning and current knowledge of the process. Looking at Figure 3.2.4, the design space is known. To identify precisely in detail what the alternative solutions are, as well as to compare the alternatives, the most important parameters for the development of an SGS concept are sought for through a brainstorming session.

These parameters initially comprise:

- The shape and material of the conveyor belt
- Whether or not the machine can handle trays (be adaptable, somewhat universal to multiple products)
- If the packaging step is part of the SGS processor or comes directly after
- The leakage control; how to avoid CO_2 emissions
- The energy consumption

As well as a portion of parameters that are related to the SGS processing time:

- Size and number of fish
- Time for each fish to be processed
- Speed of the belt
- Configuration of CO_2 jets

The latter four parameters are ignored at this point, as they require more knowledge than acquired so far in this phase.

In terms of belt shape and material, the material should be standard, easy to clean and in line with hygienic regulations (e.g. oil and grease resistant), while the shape should be ribbed (not slippery), not too rough (to avoid ruptures), have holes to increase CO_2 availability from all angles, and have a width dependant on the number of fillets and overall FPE size. Looking at the "tray/no tray" parameter, having fillets come inside of a tray when entering the SGS FPE, would have pros in terms of easy sealing and consequently a time-efficient packaging, as well as being more hygienic, but it would also decrease the CO_2 availability, and therefor not be time-efficient for SGS. Since the SGS processing time is prioritized over packaging time in this concept development project, originally, there is no focus on adaptability for tray usage - although there is potential for universality consecutively. It is also quickly decided that it is unnecessary to include the packaging step as part of the SGS FPE, because, assuming slow desorption, potential pressure control would affect packaging, the packaging equipment would have size limitation and in general it would demand too complicated design compatibility. Finally, looking at leakage control and energy consumption, the latter still remains an open parameter like the SGS-time parameters. Leakage control however, is the main parameter to focus on:

The main priority after the initial parameter brainstorming is the avoiding of gas emissions. However, as the process requires CO_2 usage, the volume must be completely closed off before the gas is added, and when the process is done, the gas must be removed or recaptured before opening. To have this process as an in-line process requires a certain speed in adding and removing the gas, also depending on the capacities and durance time of the previous and adjacent processing step (packaging). There is a wish for CO_2 flow injection over time and a circulation process of suction - purification - injection and vice versa. From this objective, the concept development can begin. The two main ideas that arise are the following:

1. **The Inlet and Outlet Lock System:**
   A gas chamber with airlocks, where the chamber has a constant pressure and continuous CO_2 injection, while the inlet and outlet locks have gas circulation and can switch to an atmospheric environment before opening.

2. **The Flow Stamp:**
   A moving gas chamber where all the parts of the process take action in the same volume. The gas chamber comes down on the belt like a piston or a stamp, has CO_2 injected, goes through the SGS process, and finally has CO_2 suctioned before the piston releases the belt as the fillets are processed and ready for packaging.

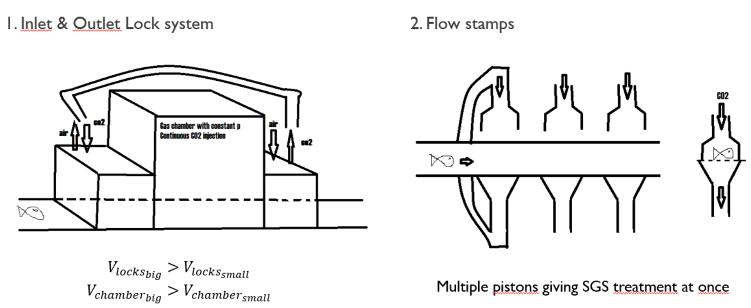

Figure 4.3.1: The early idea-drafts of both concepts.

In Figure 4.3.1 one can see the early ideas of both alternatives. While the two ideas are concrete, they also remain broad in terms of for example logistics and space usage. Several variations can be made of the two, for instance, the airlocks idea will demand doors, but it can be any type of door. On the other hand, the piston idea can consist of a floor area for the fish fillets that can have any form or shape; whatever is the most area efficient for the process. In a quick early comparison in collaboration with researchers, both alternatives have their advantages and disadvantages, dependent on what function and requirement looked at. As the product development process is done inspired by a set-based approach (subsection 3.2.3, both ideas are investigated further. However, the ideas must also be concretized and the feasibility area minimized until a reasonably detailed concept is reached and the choices that are made can be defended.

4.3.2 Requirements from the Design Criteria

The parameters of the previous section were only the initial thoughts in concept development based on current knowledge at status quo and inspiration from the physical world, as mentioned in section 4.1. Those parameters, especially leakage control, were needed in order to come up with early concept ideas. However, after this phase, the resulting design criteria defined from the SDAG assessment could also be utilized. In this way, all requirements for a sustainable FPE design could be added to the list of general requirements for industrialized full-scale in-line FPEs.

From the SDAG tool assessment the primary design criteria listed in subsection 4.2.4 are made into the following simplified requirements, in no specific order:

- Avoids yield losses of food
- Produces quality goods in line with the hygienic regulations and food safety standards in the industry, as well as avoids emissions
- Has an easy-to-clean design
- Has a time-efficient, automated, continuous line processing
- Has monitorable data

From the first and second requirements, it is clear that the FPE should have a relatively closed environment to save losses, as well as avoiding any leakage. Therefor a CO_2 circulation system is needed. While having a reasonable energy usage was an initial parameter thought of, it is no longer considered for the design phase, as it is nearly immeasurable and out of reach for this study as yet. Having an easy-to-clean design will affect the design of the concepts to some degree, i.e. in not having sharp edges and areas that are difficult to reach. As the concept will have a circulation system and CO_2 jets, there will be complex structures, and a trade-off in some measure must be made when it comes to cleanability. Having monitorable data is a requirement that can be added relatively late in the design process, so it not very much prioritized, but considered in terms of designing possibilities for addition of the needed sensors. Having a time-efficient, automated, continuous line processing does however stand out as the most related and needed requirement devised from the SDAG assessment, and will be looked further into in subsection 4.3.4.

4.3.3 Other Requirements

The requirements from the sustainable design criteria are identified. Additionally, some requirements are natural to include, not necessarily sustainable, but inevitable for an FPE design. These include:

- Having an FPE that is able to handle a large number of fish within a certain time
- Having a belt that is manufacturable and reasonable
- Having the SGS FPE in close proximity to the packaging step

Additionally, it is important to note that some requirements that are already discarded can come back later in the process. Other requirements that are secondary and still desirable to include: Having an easy manufacturing, having a belt and FPE that is adaptable to tray usage and multiple product types, having a fitting size in correspondence to the factory, ensuring reliability and durability in regards of material usage, having a responsible and reasonable material usage, and having a simple design easy to operate and learn. Some of these are still somewhat considered, as the new FPE needs to serve as a machine in the same way as all the other FPEs in the facility. This means that even though there is no prioritization of these objectives yet, and therefor are no strict constraints and regulation in terms of e.g. sizes, material usage and operation ease, there are still some limitations in these parameters as well. One cannot simply plan to create the FPE in extreme dimensions, with the worlds most expensive material and in a way that it is impossible to learn.

4.3.3.1 Fish/Time

According to the processor, 25 fillets go through the filleting machine every minute, meaning the following trimming machine handles the same amount of fillets per minute. Therefor, the concept development of the SGS FPE also takes use of this number, aiming to handle 25 fillets per minute. As the SGS process is known to be a process that takes at least 2 hours (section 2.1), an important limitation of this study comes into play. For the easy of research, it is assumed that the SGS processing time will be a total of 2 minutes instead of 2 hours. There is work on minimizing the processing time, so it is not an unreasonable assumption - and potentially, through modifications of size, the final concept solution can be adapted based on the real processing time.

Having an efficient processing line is absolutely essential for satisfying the customer needs in terms of quality and quantity, as was underlined by the SDAG assessment results. It is also entirely necessary for a continuous line processing to be able to work relative to the other processing equipment in the facility. Being able to handle a specifically large number of fish within a certain time will essentially make the FPE profitable, which is the demand of the buyers of the equipment.

4.3.3.2 Belt

The primary choice to be made regarding conveyor belts is between a monolithic conveyor belt and a modular plastic conveyor belt. In this case, a modular belt is preferred due to its versatility in accommodating varying sizes, adjustable open space percentages, capability to handle heavy loads, and ability to navigate curves. Modular belts consist of many small, interlocking parts. Although it is harder to manufacture and more costly initially, it allows for easy maintenance. Several hygienic and cleaning standards apply to conveyor belts; including standards from: the Food and Drug Administration (FDA), United States Department of Agriculture (USDA) or the European Union (EU), Hazard Analysis Critical Control Point (HACCP), European Hygienic Engineering and Design Group (EHEDG), and the International Organization for Standardization; ISO 22000:2005. [115].

The natural choice of conveyor belts are plastic belts. Plastic belts commonly incorporate a mesh structure, typically made of PVC (polyvinyl chloride) or PU (polyurethane) materials, [116]. PVC belts have a rigid weft design with a smooth or patterned top cover and patterned bottom cover. They are suitable for sliding on a stainless steel slider bed. Both alternatives comply with FDA and EU food quality standards, offer options for sealed edges and exist in different color options. PVC belts have excellent resistance to moisture, while PU belts are extra resistant to animal fats and oils. PU belts also exhibit abrasion resistance and cut resistance.

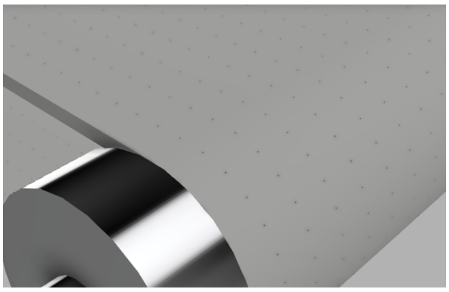

Figure 4.3.2: The monolithic belt with holes used in the renders.

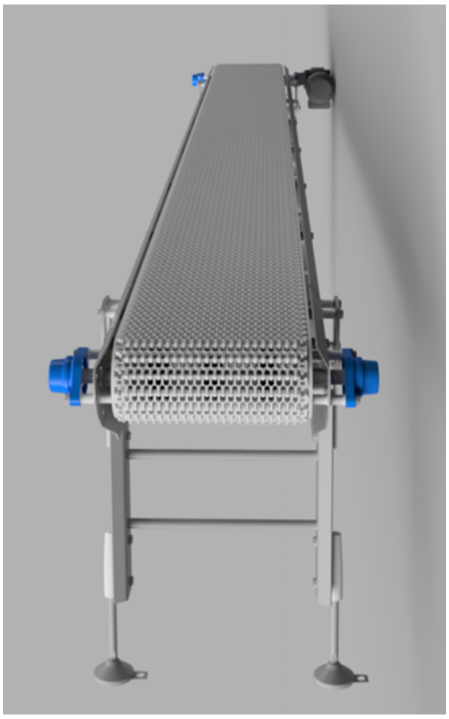

Figure 4.3.3: A modular belt design alike what is needed in the SGS FPE.

Specific examples of materials and standards can be challenging, as there is no definitive standard belt for all cases. It is recommended to explore the conveyor belt choices used by the specific facility where the SGS FPE will be implemented.

Keep in mind that the design concepts shown in section 5.1 are simplified. Although the belts in the renders look monolithic, they are not, as shown in Figure 4.3.2. Figure 4.3.3 showcases a belt texture closer to what is physically needed.

4.3.3.3 Distance to Packaging

Based on the article "Solubility, absorption and desorption of carbon dioxide in chicken breast fillets" by Rotabakk, Lekang, and Sivertsvik [117], an assumption of the time and distance between the SGS processing and packaging step can be made. Even though the article is based on the solubility of CO_2 in chicken breasts, the water content and Henry's constant of chicken $(42.8 \pm 3.7 Pa(mgkg^{-1})^{-1})$ is reported to be similar to the Henry's constant for salmon $(47.8 \pm 2.3 Pa(mgkg^{-1})^{-1})$ at the same temperature [118], and a fair assumption can be made.

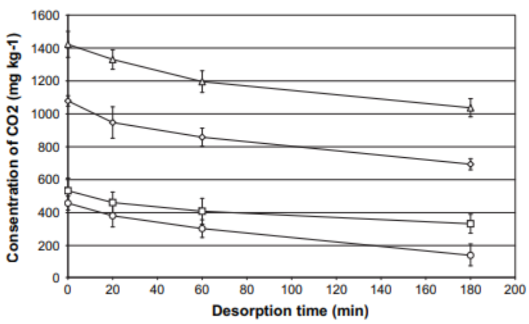

Figure 4.3.4: Concentration of dissolved CO_2 over time.

Amount of retained dissolved CO_2 (mg of 100 mg CO_2) in chicken breast fillets after different soluble gas stabilizations treatment times, followed by different time in atmospheric air before packaging in modified atmosphere.

SGS time	Time before packaging in modified atmosphere			
	0 min	20 min	60 min	180 min
2 h	100	83.1	66.2	30.6
6 h	100	86.5	76.6	62.3
24 h	100	87.8	79.6	64.3
48 h	100	93.5	84.1	72.9

Figure 4.3.5: The table belonging to the graph.
In the graph: (SGS) in 2 h (circle), SGS in 6h (square), SGS in 24h (diamond) and SGS in 48h (triangle).

Figure 4.3.4 is presented in the article, showing the concentration of dissolved CO_2 in skinless chicken breast fillets after 20, 60 and 180 minutes waiting time before packaging in modified atmosphere. Since the focus is on an SGS time of 2 hours, an online tool is used to extract values from the 2 hour line (circles) and to make a simple estimation of the concentration levels throughout the desorption time. A linear approximation using the data points over 180 minutes yields the function:

$$446 - 1.7t$$

where t is time in minutes.

However, it is clear from the graphs that the concentration has a specifically higher downhill slope the first 20 minutes relative to the following 160, so a new linear regression is made from point t=0 min to t=20 min. Additionally, the fish fillets processed in the SGS FPE should under no circumstances wait longer than 20 minutes before being packaged nevertheless. The following function for the concentration of CO_2 over a time under 20 minutes is applicable:

$$450 - 3.8t$$

where t is time in minutes.

This linear function serves as an estimation of how much CO_2 is left within the processed salmon within the first 20 minutes after the SGS process. As can be seen in Figure 4.3.5, as well as calculated with the function, 83.1% is left after the full 20 minutes. Although no maximum waiting time or minimum percentage has been set for the study, the linear approximation can be used as a constraint in future development. Preferably, the packaging happens directly after the SGS processing, but given the fact that a packaging machine like a termoformer [119] cannot take extensive numbers of fillets at once, some fillets will always have a waiting time - that should not exceed a specific duration limit. From this, the distance between the SGS and packaging step can also be modified, preferable to be as short as possible.

4.3.4 Continuous Line Processing

Having a continuous line processing is absolutely essential and is therefor written about in its own section. Looking at both alternatives proposed in Figure 4.3.1, there are some differences in the space within the processing area, as well as the time it takes for each processing step to be finished. As mentioned, it is known from the interview with the processor that the average fish/minute speed is 25 fish per minute in the filleting department. When comparing the two alternatives, the focus is on contrasting a one-level lock system with a one-piston stamp system.

A separation is made between the following:

- t_{ready} : the time it takes for 25 fillets to be ready preprocessing
- t_{inlet} : the time it takes for the inlet lock to have a CO_2-injection and air suction with 25 fillets inside
- $t_{CO_2 suction}$: the time it takes for the locks to come back to an atmospheric environment after treatment
- t_{SGS} : the time it takes for the SGS process in the chamber to be completed
- t_{outlet} : the time it takes for the outlet lock to have an air injection and CO_2-suction with 25 fillets inside

4.3.4.1 One-level Lock System

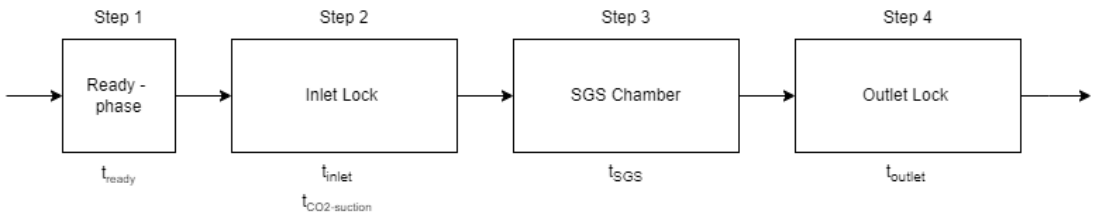

Figure 4.3.6: A figure showing the different steps of the one-level lock system.

Keep in mind that the time it takes for the conveyor belt to transfer the fillets in between the different processes, as well as the time of each gate opening in between the steps, are neglected.

0. From T=0, batch number one with 25 fillet is in the ready phase (step 1), entering the inlet lock.
1. The next step is the inlet lock (step 2). At T=1, the first 25 fillets have been treated in the inlet lock and are ready for the chamber.
2. At T=2, the first batch of fillets receive SGS treatment in (step 3).
3. Finally, the fillets arrive at the outlet lock (step 4) where there is CO_2 suction in order to make an atmospheric environment.
4. At T=4 the first batch of fillets are processed and ready for packaging.

At a first glance, the process seems fluent and continuous, but it is very much dependant of the fact that every step of T is the same. While the first batch total time is:

$t_{ready} + t_{inlet} + t_{SGS} + t_{outlet}$, the following batches include a waiting of $t_{CO_2 suction}$ before the inlet, meaning that the total processing time for a random batch is:

$t_{Locks}=t_{ready} + t_{CO_2 suction}+t_{inlet} + t_{SGS} + t_{outlet}$.

When Step 1 receives 25 fish/minute, this means that every following step must be able to handle the same amount of fish in the same amount of time. Considering that Step 2 consists of t_{inlet} and $t_{CO_2 suction}$, this means that they must equal t_{ready} together for not to create a stacking of fish. Theoretically, this means that the t_{SGS} also is the same, so the SGS process must be able to handle 25 fish per minute for a continuous process. As was mentioned in the Fish/Time section 4.3.3.1, an assumption has been made that the SGS processing time is two minutes. This leads to t_{inlet} and $t_{CO_2 suction}$ being two minutes together, but also a stacking of fillets in step 1, as there is an addition of 25 waiting fillets every two minutes. There is therefor need for a doubling of ready-phase areas, or a doubling of either intake fillets or number of lock systems.

4.3.4.2 One-piston Stamp System

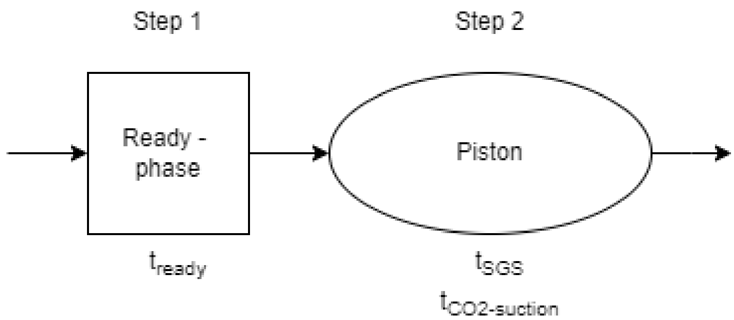

Figure 4.3.7: A figure showing the step of the one-piston stamp system.

In this case, there is only the ready-phase; step 1, and the piston phase, step 2. The piston phase in this case consists of the SGS phase, but it also includes the CO2 suctioning, because the inside of the stamp needs to have an atmospheric environment before the lid is taken off and the fillets are sent to packaging. Therefor, the total processing time in the piston equals:

$t_{Stamp} = t_{ready}+t_{SGS}+t_{CO_2 suction}$

However, in the ready-phase, 25 fish per minute are still received, and assuming a 2-minute SGS process while $t_{CO_2 suction} > 0 \approx 1$ minute, an additional 50 fillets accumulate every 3 minutes. This necessitates a threefold increase in ready-phase areas and, consequently, a tripling of pistons or intake capacity per piston.

4.3.4.3 Solution Proposition for Continuous Line Processing

The four solutions that come up from these results are:

- **A two-level lock system, where the lock can take up to 50 fillets at a time**

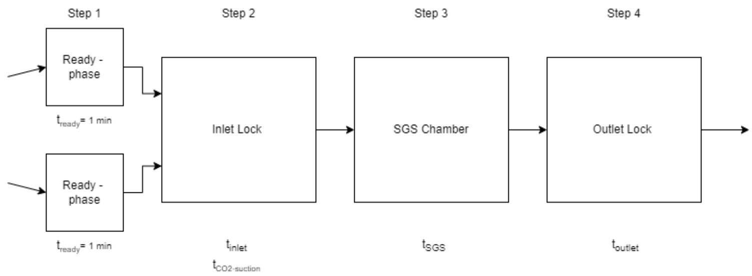

Figure 4.3.8: A figure showing locks and chamber twice the size of the initial idea.

In terms of continuity, the lock system with doubled size locks and chamber follows the efficiency function:

$$N = 25\tau - 50, \tau = 4, 6, 8, 10, ...$$

where N is the number of processed fish and τ is the number of minutes since the initial fish entered the inlet lock. This system produces 50 processed fish each 2 minutes after τ=4. Assuming the following packaging step can also handle 25 fish per minute, the last fillet of the 50-pack of SGS-treated fillets would experience an approximate 2-minute delay before being packaged, which could significantly impact CO2 desorption (discussed in section 4.3.3.3). Moreover, it cannot be guaranteed that the SGS time will remain at 2 minutes when doubling the fillet quantity within the chamber, as it is dependant that the CO_2 absorption is still the same, perhaps dependent on the CO_2 jet configuration inside the chamber. Nevertheless, implementing a two-level lock system would not substantially increase spatial requirements compared to a single-level lock system, as vertical volume expansion allows for more flexibility in terms of available area. It does however require more moving operations.

- **Two parallel one-level lock systems**

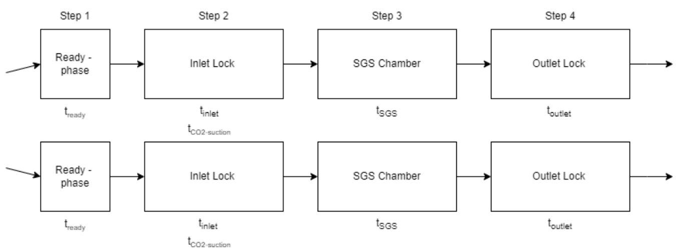

Figure 4.3.9: A figure showing two parallel lock systems.

Although the solution takes up a significant amount of space and material, the continuity can perhaps be better than the previous one. The efficiency function of the solution is:

$$N = 25\tau - 75, \tau = 4, 5, 6, 7, ...$$

where N is the number of processed fish and τ is the number of minutes since the initial fish entered the inlet lock. This system produces 25 processed fish each minute after $\tau = 4$, thereby having a much better flow, with no extra waiting times before packaging.

- **Two parallel stamp systems with one piston that takes 50 fillets at a time and another that takes 25** For this solution, there is one ready-

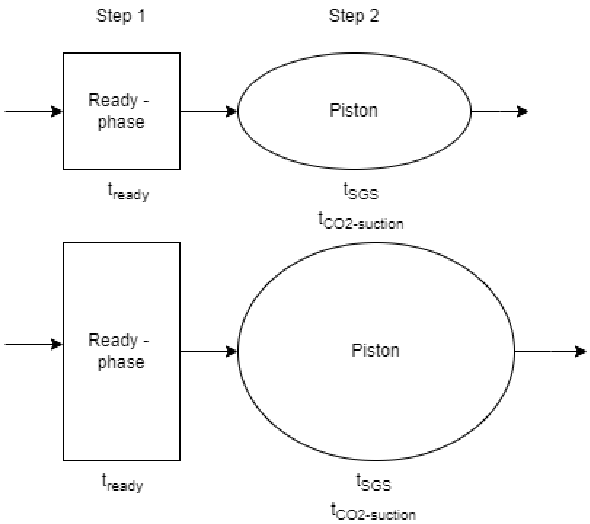

Figure 4.3.10: A figure showing a system with one normal piston and one double-sized.

phase and piston area that can handle 50 fillets at a time, and another that can handle 25. The larger one can either handle double the number of fillets by having multiple levels, or simply have a larger surface area. It will either effect the energy consumption or the space usage. It is kept as a possible solution because it will still use less volume than having three parallel stamp systems, and there is an ease of e.g. manufacturing and reduced material consumption compared to three pistons. In regards of efficiency, the same amount of fillets are processed, but the continuity is a mixture of the two previous solutions, with sometimes 50 fillets being processed and sometimes 25. Again, there will be a waiting time for up to 2 minutes for some fillets in between the SGS treatment and the packaging. The efficiency function of the solution is:

$$N = 25\tau - 50, \tau = 3, 5, 6, 8, 9, ...$$

where N is the number of processed fish and τ is the number of minutes since the initial fish entered the inlet lock. Every third τ after τ=4 is skipped.

- **Three parallel stamp systems with intake areas of 25 fillets** Having

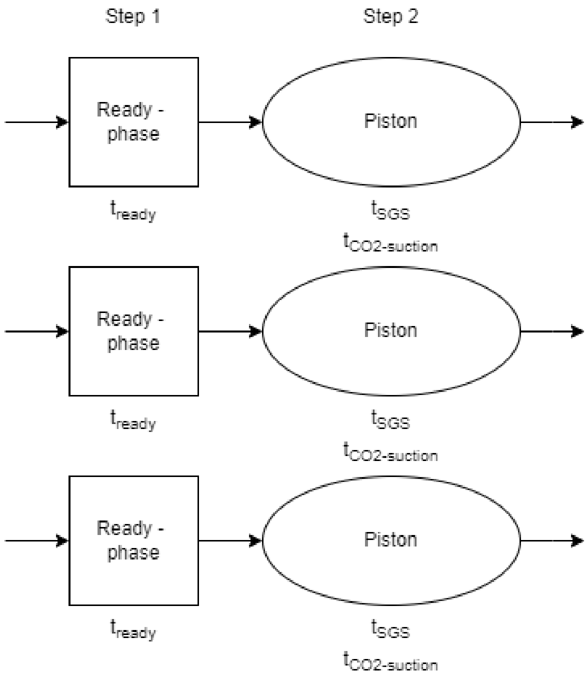

Figure 4.3.11: A figure showing tripled parallel stamp systems.

three pistons in parallel will create a more natural stream of fillets before packaging, preparing 25 fillets every minute after τ=3. The efficiency is equivalent to the other solutions, but the continuity is like the double lock system:

$$N = 25\tau - 75, \tau = 3, 4, 5, 6, ...$$

where N is the number of processed fish and τ is the number of minutes since the initial fish entered the inlet lock. Again, there is a compromise in terms of space, energy and material usage. Another difference from the double lock system is that there are package-ready fillets already at τ=3 instead of τ=4, but this can be regarded as negligible in the long term.

4.3.4.4 Logistics

Another aspect of continuity and efficiency is related to the logistics, in terms of what happens inside the chamber and piston for best possible space efficiency. Also, the exterior of the solutions could affect the efficiency. For instance, the already mentioned different alternatives in inlet and outlet components of the airlock. While the draft has a more garage-door inspired inlet, there could be a more efficient solution is having a rotating swing door. In fact, rotating airlock valves are already used in continuous Pyrolysis processes [120], but unfortunately these are not yet emission free. Since there is also no prioritization of size and no set size restriction, the logistics of the entire systems are not yet considered.

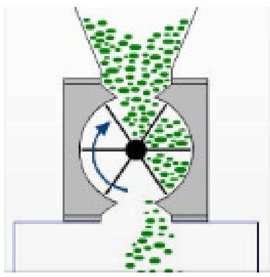

Figure 4.3.12: A small model of a rotary airlock.

Additionally, the space usage within the systems is not considered, because there is a wish to make the SGS FPE universal for all products, making it somewhat unnecessary to base dimensions on the average size of one type of fillet. There are assumption to be made on whether for instance the piston system should come together sideways instead of going downwards. Perhaps if the belt could deliver all fillets to a circular table instead of a rectangular one before the piston treats them, would the space efficiency be more efficient? These are all considerations not made this early in the concept phase, but that could become relevant later on.

4.3.5 Interview with the Manufacturer

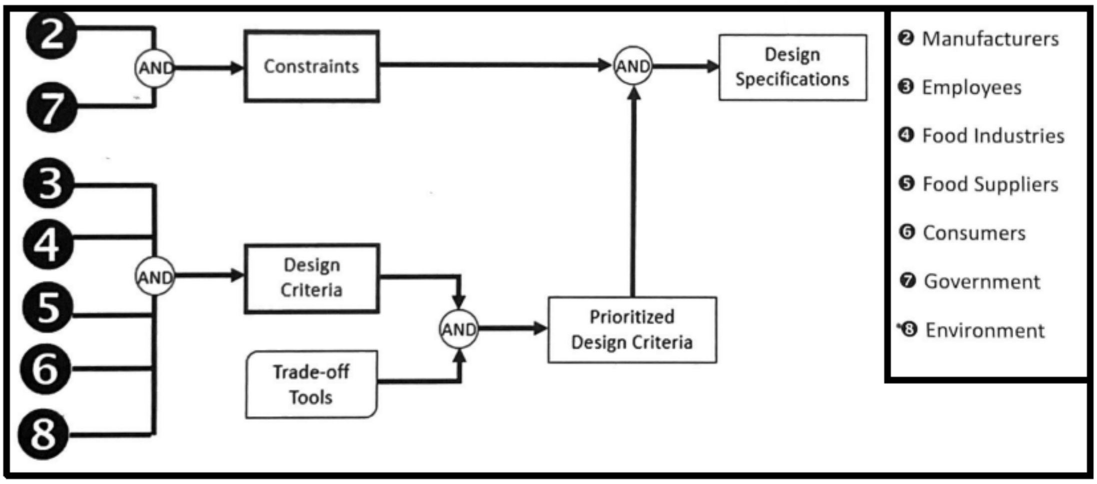

Figure 4.3.13: A reminder of the stakeholders of the project. This time zoomed in on the scope of the study.

In search of identification of all important parameters and requirements, new contact was made with the manufacturer. As highlighted previously, and zoomed in on in Figure 4.3.13, the manufacturer not only evaluated the objectives, but can also set the constraints and enablers in such a product development project. In terms of actual product development requirements, the manufacturer can be regarded as the most important stakeholder, and the stakeholder with the most knowledge within the area. While it is already established that efficiency and continuity along with producing safe quality goods are the most important requirements, the manufacturer was additionally asked what more to consider during NPD within the food industry. Many of the responses are linked to each other, but a full list of comments on prioritization is presented, to detail some of the previously mentioned and related parameters based on the manufacturer's feedback. The list decides which previously discarded criteria from i.a. Subsection 4.3.3 are still relevant. The mentioned topics will also be assigned prioritization in compliance with the indication of importance from the SDAG tool and collective interview, in the final list of requirements introduced in Subsection 4.3.6. It consists of the following:

- Capacity alignment: The equipment's capacity should match the capacity of the subsequent packing machine to ensure a seamless workflow
- Continuity: The equipment should ensure a continuous and even flow throughout the processing line. Big salmon factories prioritize maintaining a consistent flow from chopping up the fish to the packaging stage. Avoiding waiting times and the need to spread out processed fillets from large batches is crucial to maintaining continuity.
- Space usage: Somewhat consider the space requirements of the equipment, while also recognizing that if the equipment is highly desirable and beneficial, clients will make space for it
- Sorting and sequencing: The equipment should provide a chamber or system that allows for proper sorting and sequencing of fillets before packaging
- Energy consumption: While energy consumption may not be a top priority for clients, it is somewhat important to consider the overall energy usage of the equipment relative to other parts of the factory
- Cleanability and maintenance ease: Assess the equipment's cleanability and maintenance requirements, recognizing the importance of ease of maintenance for processors. While maintenance may become more complex with advanced technology, it is unlikely to be a significant obstacle for adoption in the salmon processing industry.
- Shelf life importance: Determine the percentage improvement in shelf life that the equipment offers compared to the current shelf life of the fillets and understand the level of importance that processors place on increases shelf life: Quantify the value and significance of the proposed shelf life extension to processors' operation and market competitiveness
- Freezing effects and versatility: Evaluate any potential effects the equipment's process may have on the freezing of fillets, considering the freezing practices of many processors and potential for market expansion
- Price and economy: Consider the costs associated with the equipment for both the manufacturer and the clients. Price plays a significant role in business operations, and understanding the economic impact of the investment is essential. Evaluate how the proposed equipment's benefits, such as increased shelf life, align with the customers' priorities and investment plans. In fact, [32] stated that the FPE industry perceives regulations and reduction of production cost to be the most important drivers for innovation, particularly for green innovation.
- Cost-effectiveness and return on investment: Assess the long-term financial benefits of the equipment. Processors often calculate the outcomes of their investments, considering factors such as reduced labor costs, lower maintenance expenses, and increased efficiency. Determine if the proposed equipment can provide a substantial return on investment for the processors.

Considering these parameters will help in further refining and developing the concept to meet the specific needs and priorities of processors in the industry.

4.3.6 Final List of Requirements

The final list of identified requirements consists of the following:

1. The design avoids yield losses of food
2. The design is in line with the hygienic regulations and food safety standards in the industry
3. The design has an easy-to-clean design
4. The design has a continuous line processing
5. The design has monitorable data
6. The design has leakage control with CO2 circulation to avoid emissions
7. The design can handle a significant number of fillets per time and is time efficient
8. The design has a reasonable belt usage
9. The design is in close proximity to packaging
10. The design employs reasonable space usage
11. The fillets inside the equipment are sorted nicely for the packaging step
12. The energy consumption is minimized to a certain extent
13. The design provides a significant shelf life extension of the fillets
14. The design is versatile, can take multiple products of different temperatures and is adaptable to tray usage. It can also be combined with other processes like sub-chilling.
15. The design provides maintenance ease
16. The design is investment-friendly for the clients
17. The design provides long-term financial benefits for the manufacturer

The requirements are presented in the order of which they were presented in the thesis. Numbers 1 to 6 are the specific sustainable requirements devised from the original design criteria, although all the other requirements also touch upon sustainable objectives that can be recognized in the SDAG tool.

CHAPTER

FIVE

RESULTS

5.1 Concept Details

In the results section, the two main solution alternatives to the start of a preliminary concept design of the SGS FPE are presented visually. Bear in mind that the total number of alternatives not necessarily is 2, as there are multiple ways of going forward with the two main solutions, as was introduced with the four line processes represented in subsection 4.3.4. These are only renders of a single system, and not parallel ones or different sized ones. However, for the Lock System, it does showcase a multi-level version of the design, with two elevated belts. The essence of each processing system is showcased in its simplest form. Animations of both ideas are added in Appendix C for more details and explained processes.

5.2 Renders of the Lock System

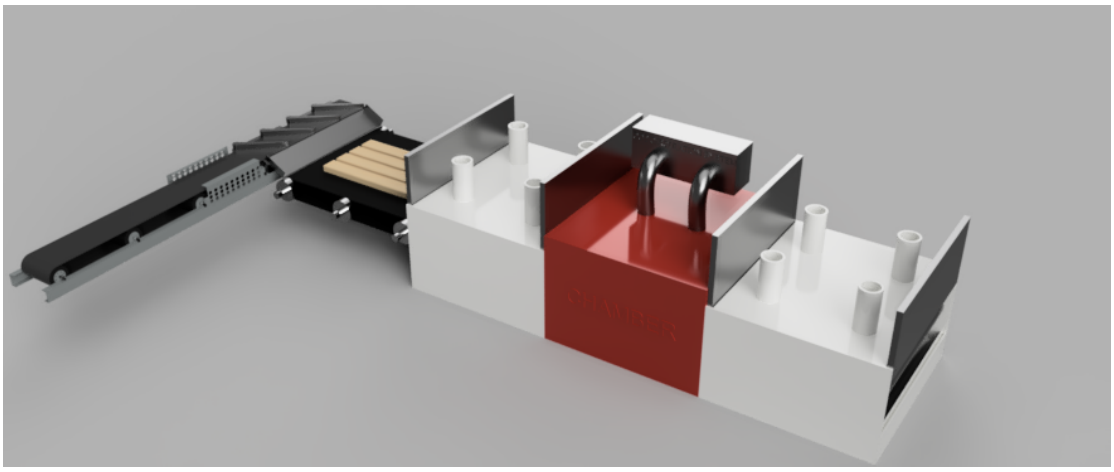

Figure 5.2.1: An overview of the lock system with an initial sorter.

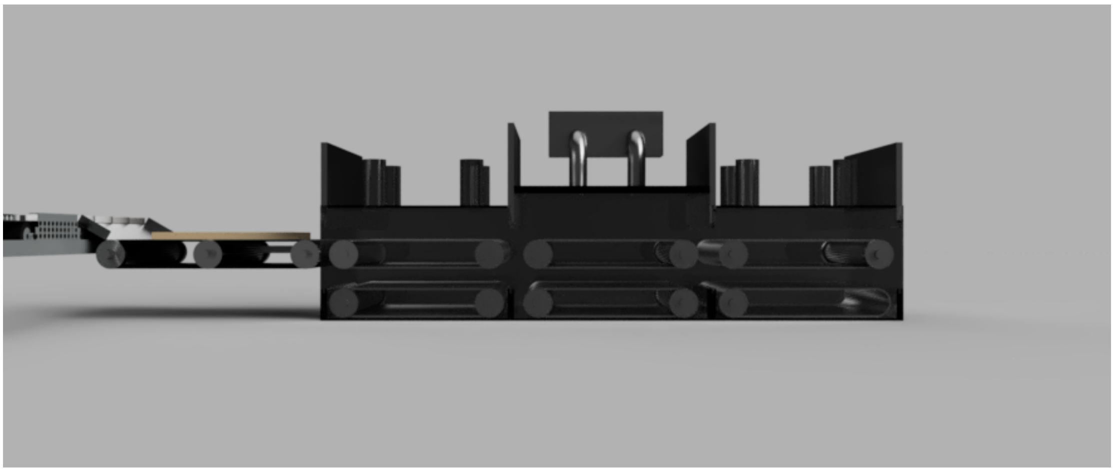

Figure 5.2.2: The inside of the locks, showcasing two-level conveyor belts.

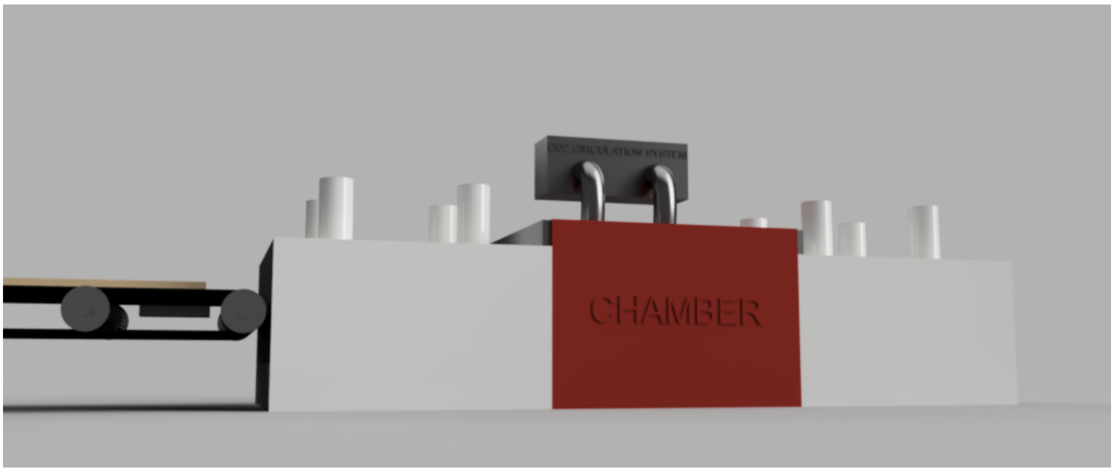

Figure 5.2.3: The system with closed gates.
The gates are not optimally designed but rather offer a simple demonstration between the different steps of the process.

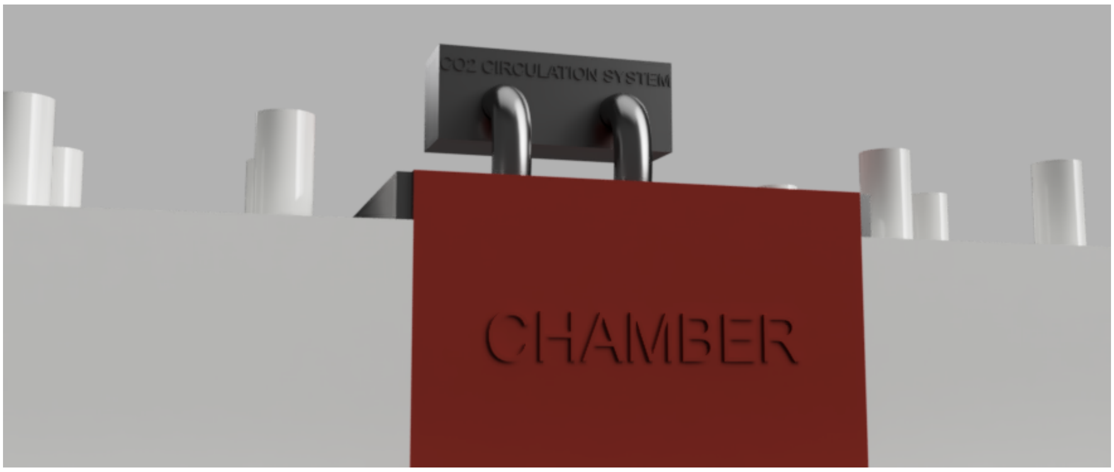

Figure 5.2.4: A close up from the chamber and CO_2 injection system.
There should also be a more complicated circulation system attached to the pipes of the locks, as described in the animations of Appendix C.

5.3 Renders of Stamp System

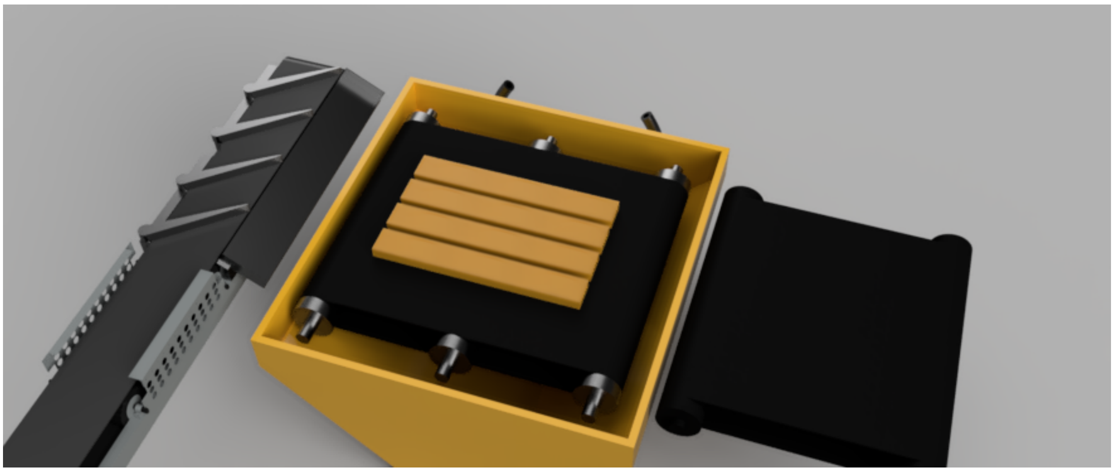

Figure 5.3.1: An overview of the open stamp with an initial sorter. The fillets are ready for SGS treatment, with the upper lid of the piston descending from above.

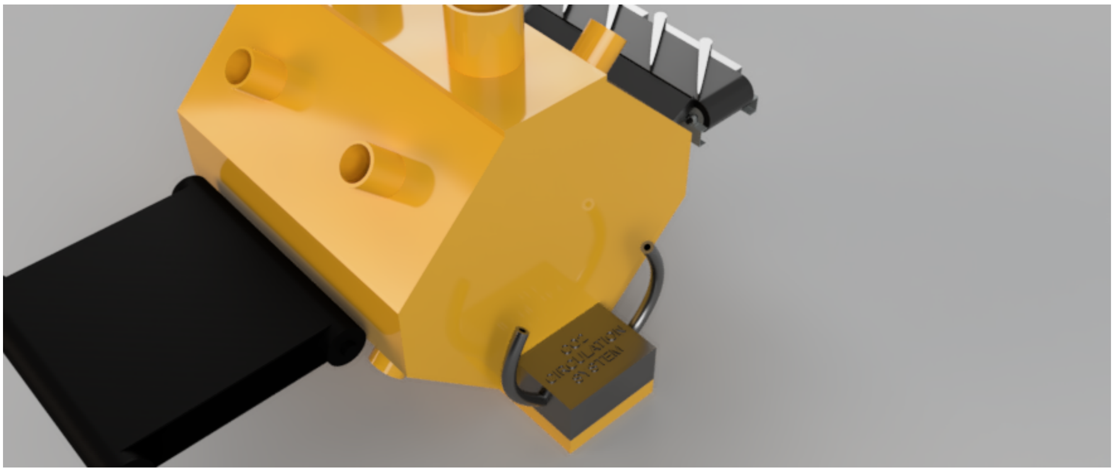

Figure 5.3.2: The stamp from behind, showing the circulation system attached. The circulation system of the render is extensively simplified and smaller than physically intended. The circulation system should additionally be attached to each CO_2-injection and -suction pipe of the piston.

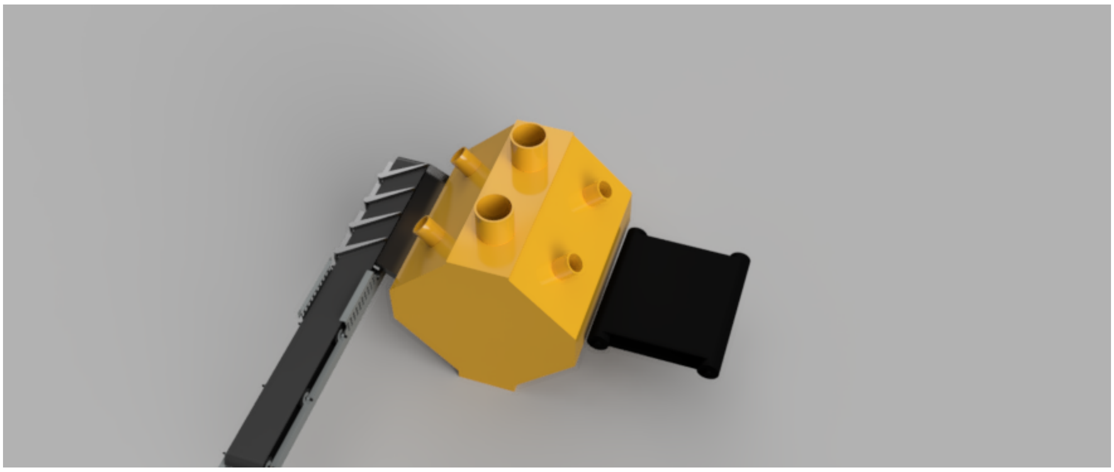

Figure 5.3.3: An overview of the closed stamp.
The fillets are SGS-treated inside the stamp, with a continuous injection of CO_2.

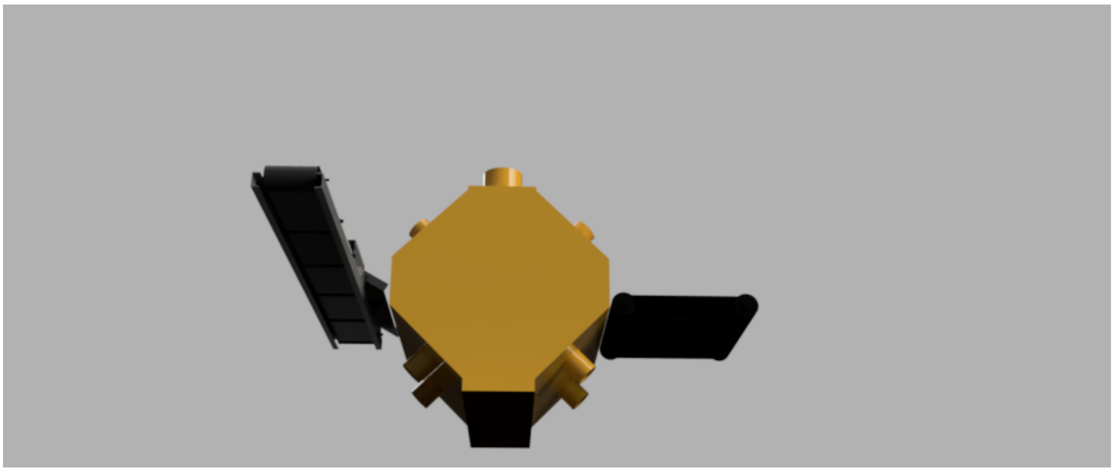

Figure 5.3.4: The stamp from underneath.
Here, it can be seen that there are also injection and suction pipes underneath the design to simplify CO_2 absorption The jet configuration inside the chamber will most probably be built in such a way that it adds CO_2 from every angle.

5.4 Prioritized Design Criteria

Since the main objective of the thesis is to develop design criteria considering sustainability performance of FPEs, and not only investigating SGS design concepts, the renders are not the only results to present. The full list of requirements that need to be considering in early FPE design was introduces conclusively in Chapter 4. While the original sustainability design criteria are included, all the other requirements are also relevant for implementation of sustainability in the concept, so the whole list can serve as design specifications. However, there is a wish for these design criteria to be prioritized. Such a prioritization is done by simple Multiple-Criteria Decision Making (section 3.4), using the weighting and evaluation scores of relevant objectives from the SDAG tool, as well as the prioritization of the manufacturer within some of the most significant themes. The results include a reasoning for the prioritization. Color codes indicate the origins of requirements within the thesis context. While all requirements are related to objectives from the SDAG tool and the final combined design criteria (subsection 4.2.4), the color codes primarily signify the sections where the requirements were fully introduced.

Prioritized List of Requirements		
Nr.:	**Requirement**	**Reasoning**
1	The design produces quality goods in line with hygienic regulations and food safety standards in the industry	The second design criteria and the first priority of the manufacturer
2	The design has a continuous line processing	The first design criteria and the second priority of the manufacturer together with efficiency
3	The design can handle a significant number of fillets per time and is time efficient	Efficiency is related to continuity and has been discussed as a manufacturers requirement, within "other" requirements, and multiple times as a sustainable design criteria
4	The design has leakage control with CO2. circulation to avoid emissions	An essential sustainability criteria, and is also prioritized by the manufacturer in "promotion of sustainable industrialization". While not being specified as a concrete design criteria, it goes as part of "promoting eco-friendliness"
5	The design provides a significant shelf life extension of the fillets	Essentially, this is the target of the SGS FPE, and the more significant the extension is, the more desirable the equipment becomes
6	The design avoids yield losses of food	An essential sustainability design criteria. Also relevant to the first secondary design criteria; optimizing potential rest raw material. Not independently assessed by the manufacturer, but avoiding yield losses of the product that goes through the FPE is essential for ensuring the meeting of market demands and customer needs, and ensures the product is treated delicately
7	The design has monitorable data	Another essential sustainability design criteria, wanted by both the manufacturer and processor. Crucial for resilience and risk analysis. Besides, the manufacturer prioritizes innovation, R&D, and adaptability to future trends, making it important to add monitorable data for sustainability
8	The design has an easy-to-clean design	While being absolutely crucial, the requirement of having food safety standards already covers some cleanability. Therefor, less prioritization is put into having *a design for* cleanability. An FPE has to be very complicated for it to be hard to clean, but simultaneuously hollow pipes or sharp corners should be avoided to ensure no microbial growth

Figure 5.4.1: Prioritized requirements from 1 to 8.
A yellow background means that the requirement is part of the original final design criteria, firstly introduced in subsection 4.2.4, while a green background indicates taht the requirement was fully described in the interview with the manufacturer subsection 4.3.5. Keep in mind that many of the requirement are intertwined.

9	The energy consumption is minimized to a certain extent	While initially assumed to be an important factor given the SDAG results from the processor and the sustainability relevance of energy consumption, energy is not really prioritized unless the numbers are very significant in relevance to the industry
10	The fillets inside the equipment are sorted nicely for the packaging step	This requirement has been added by the manufacturer quite late, but is essential for processing facilities in ensuring the all important continuous line processing. More efforts must however be invested in the logistics
11	The design is in close proximity to packaging	While affecting both the quality of the product and the process efficiecny, it was found that there will always be some waiting time anyways. As long as the time does not exceed extreme numbers, it will be okay, so it is not very significant if the actual distance between the equipments is 1 meter or 5
12	The design is versatile, can take multiple products of different temperatures and is adaptable to tray usage. It can also be combined with other processes like sub-chilling	Most of the FPEs in the industry focus on specialized products rather than being universelly applicable, so it is less prioritized, especially combining proccessing methods. However, it could expand the market, affecting economy
13	The design provides maintenance ease	While initially being a highly prioritized and evaluated objective by the manufacturer, it was also said that maintenance rarely becomes a significant obstacle for adoption in more complex advanced FPEs, especially when versatility is also less prioritized
14	The design employs reasonable space usage	A much anticipated objective, but as was stated by the manufacturer; if the product is highly desirable and beneficial, space has almost no restrictions
15	The design has a reasonable belt usage	Still an important requirement, but it has not been independently addressed by any stakeholder, as it is simple to include. Multiple belt designs are available, but it is important to follow the material standards
	The design is investement-friendly for the clients	Not considered
	The design provides long-term financial benefits for the manufacturer	Not considered

Figure 5.4.2: Prioritized requirements from 9 to 15.
A blue background means that the requirement was introduces as a reasonable addition in "other requirements" in subsection 4.3.3. The green background remains requirements described in the interview with the manufacturer, while the grey background indicates economic requirements that are important, but not evaluated, prioritized or considered relevant specifically for sustainability implementation.

The final two requirements that originate from the manufacturers interview are not less prioritized, but are factors not considered or addressed at this stage. Although it is evident that investment costs and incomes are very much prioritized by the industry and generally in new product development, the economic requirements are not part of the prioritized list as they are not necessarily part of sustainability implementation, in the same way as for instance "economic viability". The actual price factor that decides investments costs and potential earnings is unknown at this stage and very much dependant on other requirements. However, since most companies are profit-oriented, it is important to include and would most probably be at the very top of the list of prioritizations.

CHAPTER

SIX

DISCUSSION

6.1 Discussion of Results

The results of the renders are intended to be early drafts of the concept design. They are in no way meant to be final solutions, rather function as guiding fictional prototypes. Therefor it is also not needed to go into the depth of the details, such as jet configurations. Again, the logistics of the setup remain yet to be decided. Additionally, the functionality and final design of the CO_2 circulation system still needs research. Since most of the exact sizes and times are quickly assumed and not concretely estimated, the dimensions are also not necessary to include.

Together with the results of the current prioritized design specification list, the design alternatives can evolve to finally be optimized solutions in the future. The SDAG tool in collaboration with both the processor and the manufacturer, as well as the more extensive interview with the manufacturer, has provided a reasoned list of criteria that can eventually create a fully complete list of design specifications for a preliminary design of up-scaled in-line SGS FPEs.

Going back to the motivation section of the introduction, some questions were asked: Firstly, *"Which parts of sustainability are evaluated to be the most important for different stakeholders?"* which has been directly answered with the design criteria. Secondly: *"Can the social sustainability be forgotten as long as the economic sustainability is great?"* No, all aspects of sustainability need consideration in order to implement a sustainable practice. Most companies are profit-oriented, but being sustainable involves more than economic prosperity, namely social equity, environmental protection and innovation. Thirdly: *"Does a high energy consumption really matter if the processing equipment extends the shelf life of its products?"* Actually, the research found that high energy consumption is less prioritized than initial expectations after the processors SDAG assessment. Moreover, since extending the shelf life of the product is fundamentally the primary objective of the SGS process, it naturally receives higher priority, as evident from the prioritized list of requirements. However, there will always be trade-offs and this does not necessarily mean that the energy usage can be sky-high as long as the product has extended shelf life.

Notably from the results, the manufacturers assessment of the SDAG tool had relatively little differences from the processors assessment. The biggest differences were e.g. within energy consumption, or were capacity-, locality- and client-dependant objectives. These differences slightly modified a combined list of essential, sustainable design criteria. However, in order to actually develop a sustainable product in the SGS FPE, the more extensive list was created, including all other requirements in NPD. By involving all requirements and creating a prioritized order, the list can be used to identify the optimized solution as well as serve as recommendation guidelines for all industry stakeholders on how to improve the sustainability performance of already existing FPEs.

That being said, many assumptions have been made to reach this far in the concept development phase. For instance, the current four solution ideas suggested and compared in Appendix D are all based on the assumption that the SGS processing time is reduced to 2 minutes instead of 2 hours. While there are possibilities for improvement, such improvements will most probably also affect other aspects, such as the desorption time and therefor proximity to the packaging step. However, the thesis has laid a foundation for calculations and considerations when it comes to the most relevant parameters to consider, and offers a roadmap in case of changed parameters.

Additionally, many design criteria or requirements have been discarded while possibly being very attractive for other stakeholders than the two participants. Some of these include the combination possibilities with other processing methods, conclusively introduced in section 2.1, or the adaptability to tray usage, which will simplify packaging and make the process more universal. It is only assumed that the CO_2 availability is affected by tray usage, not proven, and therefor the adaption should still be considered a possibility.

In terms of the limitations introduced in the introduction, the thesis has been very much affected by reduced stakeholder involvement and only somewhat by the resource rent tax. However, the full effect of the tax is yet to be seen. In terms of short-termism and general issues of SDGs, it will be up to the companies that can utilize the resulting guidelines whether these limitations affect them. However, the study has revealed an increased interest in sustainability, and as underlined by the manufacturer; sustainable industrialization will soon be on par with efficiency and continuity as a prioritized objective. Therefor, there is reason to believe that businesses will align objectives and strategies to achieve sustainable outcomes and have sufficient monitoring of sustainability achievements.

6.2 Project Advancements

It is important to look back at the product development theory, since most of the introduced approaches showcase a long and holistic approach, of which concept development is only the beginning. Looking back at the product development methods that were drawn inspiration from in section 3.1, it is not difficult to see where the project currently is. While remaining in the concept development phase for some while when it comes to the conceptual framework of SBD, the actual approach of the project reminisces somewhat the one introduced by SBD, showcased in Figure 6.2.1.

This is a model showing how the approach reflects the SBD approach introduced in Figure 3.2.4. In point 1, the design space was mapped, while at phase 2, multiple alternatives where found within the two original functionality groups.

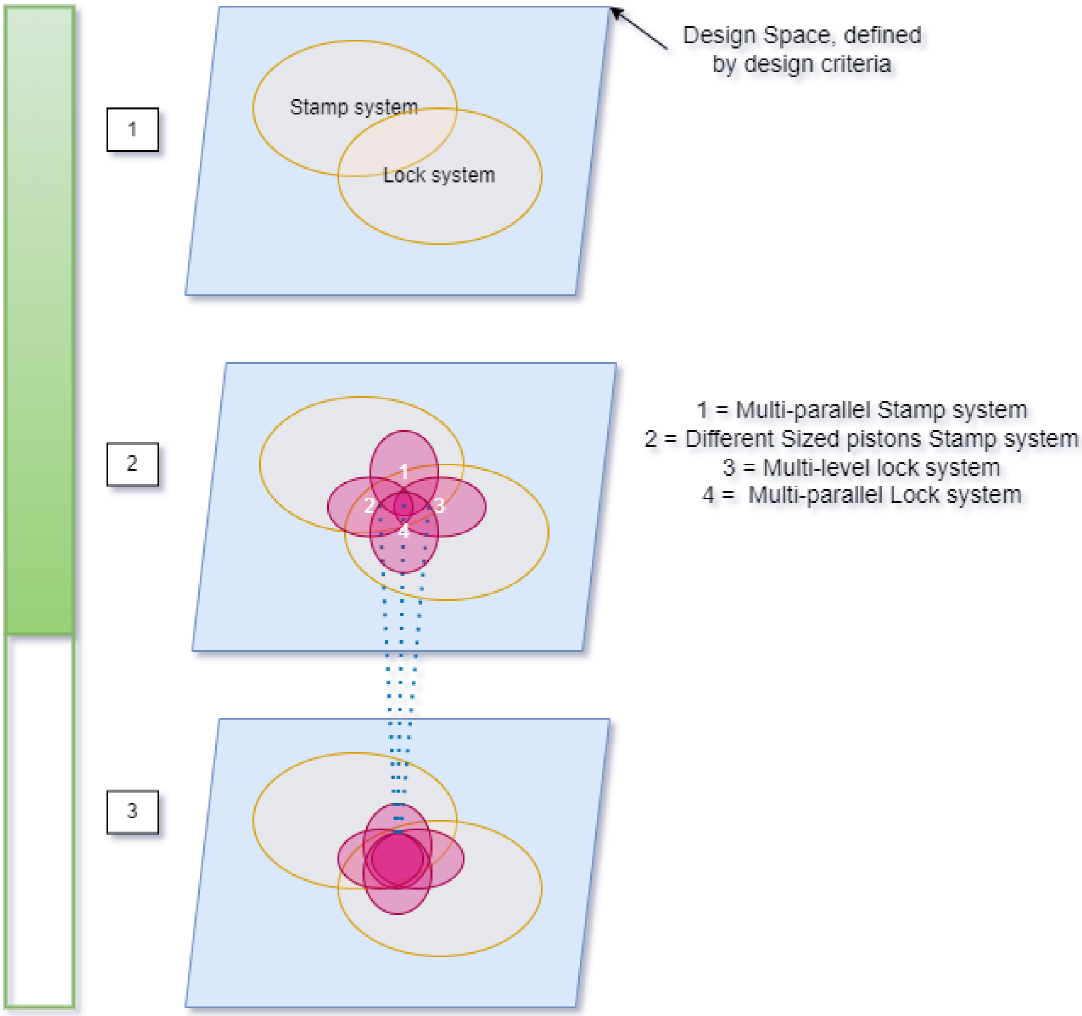

Figure 6.2.1: SBD-inspired approach that can be continued.

As exhibited by the progress bar, the process has not reached the next phase, but in theory, when investigating and exploring the solution alternatives, the intersections of the independent solutions need to be investigated further and expanded, before eliminating unfeasible regions and narrowing the solution space into an optimal design. In the case of the study, the solution alternatives have regions of overlap in many of the identified requirements, as will be shown in section 6.3, meaning that these most probably are feasible and demanded regions to explore further, and any other solution can be discarded.

While not having the possibility to do complete concurrent engineering by not being a team and not being able to have multi-stakeholder meetings - some of the concurrent engineering aspects have been considered. A holistic view of the product has been utilized and all information used in design decisions are seemingly as correct as possible. Also, the concurrent flow introduces in Figure 3.2.1 can still happen, and time can still be saved, it is only too early to determine, given that the concept stage is the first of many phases. Possibly, the stakeholders will participate in concurrent engineering practices in the future. In terms of systems engineering, the key points have all very much been emphasized, with a comprehensive look at multiple factors, underlining that all components (and humans) interact with each other throughout the life cycle.

It is almost unnecessary to look back at the introduction of Sustainability-Oriented design, Design for Environment and Sustainability by Design, because it is evident that the SDAG tool has taken care of utilizing and emphasizing most of these frameworks. All key-points to take away from the Sustainability by Design strategy are included as much as possible: Stakeholders have been able to participate equally from a status quo, the entire life cycle of the project has been considered multiple times, efficiency has been optimized through design, considerations have been done in terms of realizing that the FPE is part of its surrounding systems, the approach has been HSE-conscious and has aimed to reduce impacts, the project has aimed to promote equity, the project attempts to map job safety and security, and emphasizes creativity. Finally, through using the SDAG tool, the stakeholders have had the possibility to assess evaluations to all aspects relative to sustainability. Jointly, they have been creating a list of improvement areas, but most importantly design criteria that could be used to create design specifications for a preliminary design of a new FPE. The only limitation has come from the fact that they have not worked collaboratively, and not all stakeholders were included from the start, as was the intention according to the UIAs Sustainability by Design keypoints.

Nevertheless, looking extensively at the numerous product development methods introduced, they all relate to the SDAG tool and Sustainability by Design, which have lead to the creation of sustainability guidelines. As mentioned in subsection 3.3.2, a life cycle assessment performed by Bar [32] found that none of the researched food processing companies in their report employed DfE methods, mainly because they were too complicated. There was generally a limited understanding of how different FPEs impact the environment within the industry. Therefor, a change was required. By creating a tool that is easily adaptable, understandable and implementable, that change can take place, and provide sustainable design guidelines. This guideline is not like a DfX tool despite being inspired by it, but has rather combined systems engineering, some set-based concepts, and sustainability-oriented objectives within a Sustainability by Design framework.

Looking at the workflow-chart it is clear where the project is positioned, and what is needed further. While the green checkpoints indicate what has been completely settled in the study, the yellow ones indicate where there is still some work to be done, and the orange arrow indicates approximately where the progress has arrived. Even though the listed requirements combined with constraints can serve as design specifications for a preliminary design, not all stakeholders are considered independently, indicating why the complete prioritization of design criteria is not done yet, and why it is unsure that all constraints are set. As was discussed in limitations (subsection 1.5.1), some of the stakeholders are still somewhat represented through the results of the food industry stakeholders, therefor depicted with a checkmark in brackets; but optimally they should all be considered individually. However, for the sake of the study itself, which mainly aimed to include the manufacturers viewpoints, it can be said that for now, the specific design specifications are set, and that combining these with the concept development is currently closing in on the "preliminary design" phase in Figure 2.2.2.

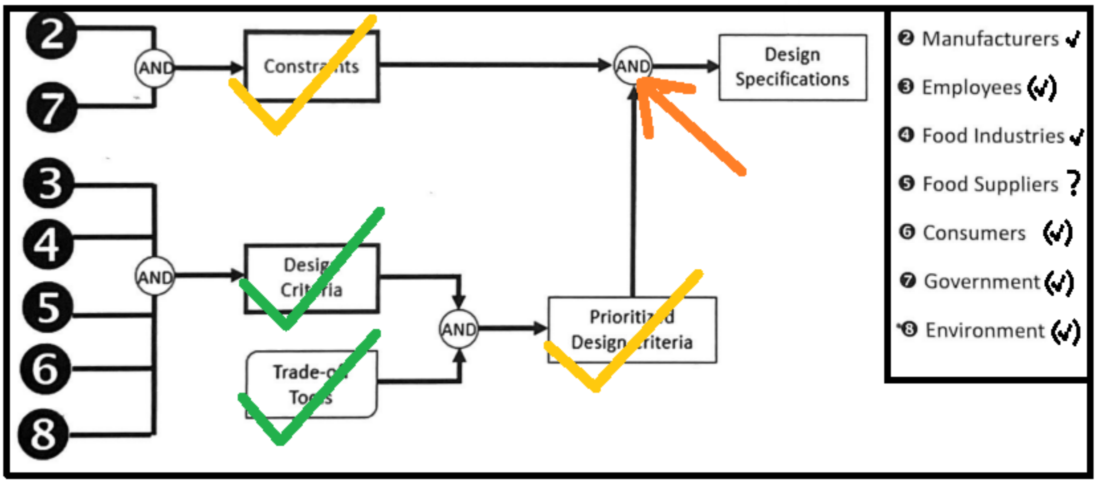

Figure 6.2.2: The current state of the workflow.

6.3 Comparison of Solution Alternatives

Conclusively in the discussion, the solution alternatives can be shortly compared, to showcase how the prioritized design criteria can function in identifying feasible regions and optimized solutions. As can be seen from the color codes of the final list, most of the highest prioritized objectives include the specifically sustainable design criteria from the SDAG tool. As said multiple times, most of the other added requirements from the manufacturer include sustainability aspects as well. This highlight the original scope of the thesis and underlines that the main objectives introduces in section 1.2 have been answered.

When comparing the solution alternatives, it can become clear how the different solutions solve the requirements. Some of the requirements remain unknown or are very much alike between the solutions. However, the dissimilarities between the functional solutions can identify which is the better solution based on a prioritized requirement. An example of such a comparison is added in Appendix D. Keep in mind that this is not considered results for the entire thesis, but rather an attempt to showcase and discuss how the list of prioritization can be utilized in future phases of the concept development. The functional solutions of the comparison are based on what was found in subsection 4.3.4. For future work, this assessment should be done to a more comprehensive degree.

CHAPTER

SEVEN

CONCLUSIONS

7.1 Conclusion

In conclusion, the main objective of this thesis was to establish guidelines for the implementation of sustainability objectives. By utilizing an SDAG tool inspired by sustainability-oriented innovation, design for environment, and sustainability by design, these guidelines have been successfully developed. The SDAG tool has effectively been applied, involving the most crucial stakeholder; the manufacturer, and previously the processor, in the assessment process. This has led to the creation of a combined, concrete list of primary and secondary design criteria, which were subsequently integrated into a holistic set of requirements. These requirements with constraints serve as the design specifications that guide the evaluation of various sustainable preliminary design alternatives for the SGS FPE, with specific emphasis on the inlet and outlet configurations.

Employing a systems engineering approach, influenced by set-based product development principles, the configurations have been refined, guided by the design specifications. Although no definitive solution has been identified, the four final equipment designs can be thoroughly assessed for their sustainability impact using the guidelines based on the existing food processing industry's sustainability performance and the resulting SDAG tool. Overall, the study has not only identified areas of improvement for the existing industry in terms of implementing sustainability, but has also created sustainability design criteria to the product development process of potential industrial up-scaled of SGS FPEs. Ultimately, all expected outcomes have come true.

Addressing the research question, *"how to prioritize the significance of sustainability to be integrated into the design phase of the industrial up-scaling of food processing technologies"*, the thesis has provided a substantial answer. The significance of sustainability is of utmost importance and continues to gain prioritization. However, integrating sustainability into the design phase of a new product remains challenging, as considerations such as continuity, efficiency, and costs tend to take precedence, particularly in industrial up-scaling. Nonetheless, sustainability is becoming increasingly interconnected with these factors.

7.2 Future work

By consolidating findings, proposing guidelines, and highlighting the growing importance of sustainability, the thesis contributes to the ongoing dialogue on sustainable design in the food processing industry. It emphasizes the need for continued efforts to integrate sustainability objectives into the design phase and paves the way for future research and practical implementation in this vital field.

The discussion has taken care of showcasing some of the lacking areas of the study at the moment: stakeholder involvement, assumptions made and discarded criteria. As many times repeated, there is also a wish for the future of the product development to be done in a multi-stakeholder environment, where the different stakeholders of the industry work collaboratively in defining the optimal solution. The comparison in the discussion chapter has underlined a lot of the future work in deciding which solution alternative or combination of solutions that is the best. While some requirements are clear, most are not researched enough. To be able to compare the solutions fairly, sufficient information is needed in the areas of uncertainty.

Conclusively, it is imperative to dedicate more effort towards defining the design specifications for SGS by conducting a comprehensive assessment based on sustainable design criteria. Notably, one objective remains partially unanswered, as only a few alternatives have been explored towards reaching a final preliminary design rather than a fully developed preliminary design concept. A complete set of design specifications will further contribute to addressing the research question on how to prioritize sustainability in the design phase of scaling up food processing technologies. While the thesis has demonstrated a growing prioritization of sustainability implementation, it remains uncertain whether sustainability will retain its priority as the product development progresses and other appealing aspects come into play. Many companies are profit-driven, and although efficiency and economic viability also align with sustainability, it is crucial to incorporate multiple sustainable objectives. By integrating sustainability as a foundational element during the design phase of a new product or establishing sustainability as a core company value, its inclusion throughout the entire lifecycle can be ensured. The comprehensive list of prioritized design criteria, with a strong emphasis on the most sustainable objectives, must be diligently finalized, considering all relevant stakeholders. Upon completion, the list should be promoted and utilized in both existing FPEs and new products in the field of food processing technologies. If successful, the list serves as compelling evidence for the profound importance of integrating sustainability in the early stages of the design process, applicable even to the industrial up-scaling of various technological domains beyond food processing exclusively.

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APPENDICES

A- SDAG tool: Processor

ENVIRONMENT DIMENSION: Seeks to address the need for a quality natural environment and for sustainable resources.

	Themes Goals	Weighting	Justification for weighting	Assessment	Actions planned or already implemented	Opportunities for improvement	Priority	Data quality index: Correlation	Status	Reliability	Data quality	Data needs	Note 1	Note 2	Note 3	Note 4	Note 5	Priority	Data	Data collection
1	**Ecosystems**																			
1.1	Minimize yield loss of main food product from raw material during processing	3	Fish farming and harvesting have obvious correlations with ecology, sea-ecosystem, capacity, etc.	90	Already a lot of knowledge and research, the company has own employees in research department	As always: Always room for some improvement, participate even more in research, etc.	Maintain				#DIV/0!	#DIV/0!	2,7	###	###	###	#REF!	393	#DIV/0!	#DIV/0!
1.2	Facilitate optimal utilization of rest raw material for human consumption	2	Important to follow regulations	70	The company follows all the regulations required	Potentially, the company could also themselves create more regulations or interfere more with partners that perhaps have more potential for improvement on this aspect	Maintain				#DIV/0!	#DIV/0!	1,4	###	###	###	#REF!	272	#DIV/0!	#DIV/0!
	Average weighting : Ecosystems	**2,5**	**Weighted performance : Ecosystems**	**82 %**																
2	**Resources**																			
2,1	Minimize energy consumption	3	Energy will be one of the things the company consume the most as they have a large, automated, generally high tech. factory	77	Even though there are only short periods of time that there are no people working in the factory, there are possibilities for improvement when it comes to turning off machines and lighting when not in use	Reduce power and lightning usage when production is off	Maintain				#DIV/0!	#DIV/0!	2,3	###	###	###	#REF!	380	#DIV/0!	#DIV/0!
2,2	Minimize food grade water consumption	3	A lot of water is used during a day in the factory, and a lot of it has to be bought municipally	78	There have been talks about the factory cleaning/destilling sea water themselves in order to use it as freshwater, but it is not up and running yet	Cleaning sea water themselves to reduce use and costs	Maintain				#DIV/0!	#DIV/0!	2,3	###	###	###	#REF!	381	#DIV/0!	#DIV/0!
2,3	Design for better cleanability	2	It is important, but the company is not responsible for the specific design, only choice of manufacturer.	80	The cleaning is done with a strict regime, systematically, the manufacturer is chosen with care and is consequent throughout the whole factory	Always potential through even more collaboration with manufacturer	Maintain				#DIV/0!	#DIV/0!	1,6	###	###	###	#REF!	282	#DIV/0!	#DIV/0!
2,4	Reduce the use of materials for the equipment construction	2	This is again not really up to the company itself, more the manufacturer, but it is considered when deciding	70	The process required a high complexity machine, obviously involving multiple complex, expensive and "more rare" materials	Always potential through even more collaboration with manufacturer, material research and product development	Maintain				#DIV/0!	#DIV/0!	1,4	###	###	###	#REF!	272	#DIV/0!	#DIV/0!
2,5	Choose low-impact resources	2	Again, more relevant for manufacturer, but also when choosing other resources, for instance ligthning	80	Somewhat considered for stuff as lightning, cleaning articles, etc.	Always room for improvement unless you are the greenest company in the world	Maintain				#DIV/0!	#DIV/0!	1,6	###	###	###	#REF!	282	#DIV/0!	#DIV/0!
2,6	Plan for the prudent use of renewable resources	2	As above	80	As above	As above	Maintain				#DIV/0!	#DIV/0!	1,6	###	###	###	#REF!	282	#DIV/0!	#DIV/0!
2,7	Plan for the prudent use of non-renewable resources	2	Not considered	77	Not considered	Not considered	Maintain				#DIV/0!	#DIV/0!	1,5	###	###	###	#REF!	279	#DIV/0!	#DIV/0!
2,8	Optimize resources that are at the end of their life	2	Not considered	78	Not considered	Not considered	Maintain				#DIV/0!	#DIV/0!	1,6	###	###	###	#REF!	280	#DIV/0!	#DIV/0!
	Average weighting : Resources	**2,3**	**Weighted performance : Resources**	**78 %**																
3	**Output**																			
3,1	Identify liquid, solid and gaseous outputs and the impacts on the environment	1	Identifying these outputs is the first thing to do in order to minimize them, which is a much higher priority than just identifying them. There are almost no outputs anyway	100	There is full controll on the outputs, in fact, the only real output is the "blood-water" which is sent directly to a cleaning facility.	No improvement potential	Non-priority				#DIV/0!	#DIV/0!	1	###	###	###	#REF!	201	#DIV/0!	#DIV/0!
3,2	Reduce need for washing agents and disinfectant	2	A lot of washing is needed, and hygiene is important	80	A lot oThe factory is washed after a shift, meaning a lot of waste gathers up before being washed away. This already may have reduced amount of cleaning agents, but there is always room for potential improvements.	Optimize cleaning routines	Maintain				#DIV/0!	#DIV/0!	1,6	###	###	###	#REF!	282	#DIV/0!	#DIV/0!
3,3	Minimize noise emission	3	A big factory with a lot of export and traffic related to it, obviously produces a lot of noise that should be minimized	70	Noise inside the factory are not necessarily a treat to health or environment, but sounds outside can impact environment, which can possibly be reduced	There is always room for improvement for reducing noise emissions. The most normal ones come from transportation. Loud noices from machines can also be reduced through controls.	Maintain				#DIV/0!	#DIV/0!	2,1	###	###	###	#REF!	373	#DIV/0!	#DIV/0!
3,4	Minimize odor emission	1	There are nearly no odor emissions affecting the environment	70	A good cleaning is implemented to avoid these odors. The odor emissions are deemed little likely to prioritize, as the working environment deal with them and they are no treat to surround environment.	There is potential of minimizing the odor as nothing more than good ventilation is done for employees to avoid extreme odors	Non-priority				#DIV/0!	#DIV/0!	0,7	###	###	###	#REF!	171	#DIV/0!	#DIV/0!
3,5	Minimize liquid effluents	2	This is an industry with a big amount of liquid discharges, and a liquid waste treatment plan is required	80	Follow rules from municipal, county and country. The factory has put a lot of efforts into this with new equipment like fat-seperators and cleaning the water with chlorine to make it as clean as possible	There is still more potential since the amount is so large	Maintain				#DIV/0!	#DIV/0!	1,6	###	###	###	#REF!	282	#DIV/0!	#DIV/0!
3,6	Minimize solid wastes (sludge, used chemicals ...)	1	Not really relevant as the only real output is blood water, while rest raw material are also considered valuable	80	Follow rules from municipal, county and country. When it comes to actual fish loss (fallen on the ground) it is packed in seperate packages and sent away for feeding animals.	Even though solid wastes are currently resources for animal feeding, there is potential in avoiding these wastes to a higher degree	Non-priority				#DIV/0!	#DIV/0!	0,8	###	###	###	#REF!	181	#DIV/0!	#DIV/0!
3,7	Minimize impacts	3	Should be a high priority in all factories	80	Follow rules from municipal, county and country	Some of the above opportunities fit in here as well. By following the regulations, it is already somewhat optimal, but there is always potential for more research or even more controls	Maintain				#DIV/0!	#DIV/0!	2,4	###	###	###	#REF!	383	#DIV/0!	#DIV/0!
3,8	Manage hazardous waste properly	1	Not considered relevant	80	Answerer feels as if there is no hazardous waste, and if there is, it is managed properly	Not considered	Non-priority				#DIV/0!	#DIV/0!	0,8	###	###	###	#REF!	181	#DIV/0!	#DIV/0!
3,9	Limit global pollutant emissions	1	Not considered relevant as these emissions are not really there	80	Not considered	Not considered	Non-priority				#DIV/0!	#DIV/0!	0,8	###	###	###	#REF!	181	#DIV/0!	#DIV/0!
	Average weighting : Output	**1,7**	**Weighted performance : Output**	**79 %**																
4	**Climate change**																			
4,1	Quantify greenhouse gas emissions	1	Not considered relevant	90	Not considered	Not considered	Non-priority				#DIV/0!	#DIV/0!	0,9	###	###	###	#REF!	191	#DIV/0!	#DIV/0!
4,2	Reduce GHG emissions	1	Not considered relevant	90	Not considered	Not considered	Non-priority				#DIV/0!	#DIV/0!	0,9	###	###	###	#REF!	191	#DIV/0!	#DIV/0!
4,3	Compensate for greenhouse gas emissions	1	Not considered relevant	90	Not considered	Not considered	Non-priority				#DIV/0!	#DIV/0!	0,9	###	###	###	#REF!	191	#DIV/0!	#DIV/0!
4,5	Reduce Atmospheric emissions (exhausted gases, steam, ...)	2	Can be somewhat relevant	90	Most technology in the factory does not produce emissions	Electrify all transport related to the factory	Maintain				#DIV/0!	#DIV/0!	1,8	###	###	###	#REF!	292	#DIV/0!	#DIV/0!
4,6	Plan for adaptation measures to respond to the new climate reality	1	Not considered relevant	90	Not considered	Not considered	Non-priority				#DIV/0!	#DIV/0!	0,9	###	###	###	#REF!	191	#DIV/0!	#DIV/0!
	Average weighting : Climate change	**1,2**	Weighted performance : Climate change	**90 %**																
	Average weighting : Ecological dimension	**1,8**	**Weighted performance : Ecological dimension**	**80 %**																

A- SDAG tool: Processor

SOCIAL DIMENSION: Seeks to address social needs, individual and collective aspirations, health and well-being needs, and quality of life needs.																				
								Data quality index												
Themes Goals		**Weighting**	**Justification for weighting**	**Assessment**	**Actions planned or already implemented**	**Opportunities for improvement**	**Priority**	**Correlation**	**Status**	**Reliability**	**Data quality**	**Data needs**	**Note 1**	**Note 2**	**Note 3**	**Note 4**	**Note 5**	**Priority**	**Data**	**Data collection**
1	**Food**																			
1,1	Ensure food safety during processing	3	"Self explanatory" in the food industry. This is what makes their living, so there is a lot of pressure and focus within food safety and security.	90	Basic training for all employees in hygiene and safety. A lot of control tests on both tools and product are done. These are sent away to check for bacteria growth. Additionally, a lot of tests are done to check if the cleaning is good enough. Multiple "Hundred-fish-controls" are done, where 100 fillets are checked to see if there are any errors or wrongs.	Potentially do more controls	Maintain				#DIV/0!	#DIV/0!	2,7	###	###	###	###	393	#DIV/0!	#DIV/0!
1,2	Ensure food security	3	"Self explanatory" in the food industry	95	A lot of control tests on both tools and product are done.	Almost no improvement potential	Maintain				#DIV/0!	#DIV/0!	2,9	###	###	###	###	398	#DIV/0!	#DIV/0!
1,3	Align the way that equipment affect food quality during processing with the consumer food preferences	3	"Self explanatory" in the food industry	90	Control tests	Possibly make an even clearer overview of the effect different processes have on the food quality	Maintain				#DIV/0!	#DIV/0!	2,7	###	###	###	###	393	#DIV/0!	#DIV/0!
	Average weighting : Food	3,0	Weighted performance : Food	92 %																
2	**Health**																			
2,1	Provide an ergonomic condition for employees	3	For the manual workers, the work can be physically exhausting, so ergonomics are important	80	Where it is possible to improve the conditions, it is done by adapting the process for the workers and providing them with	Have more communication with the workers on how to improve the comfort. Possible include mats on the floor or upgrade shoes if this is a problem.	Maintain				#DIV/0!	#DIV/0!	2,4	###	###	###	###	383	#DIV/0!	#DIV/0!
2,2	Consider gender status in ergonomic design	1	Ergonomic design is no priority as it requires minimial manual work	50	Most tools in the factory are unisex and therefor not fitted to one specific gender. There are no plans to change this and "not really a need"	Not relevant	Long term issue				#DIV/0!	#DIV/0!	0,5	###	###	###	###	151	#DIV/0!	#DIV/0!
2,3	Reduce task duration	2	It is natural that the process has tasks that can take a long time	80	The extensive implementation of automation has already improved these things, and for the trimming process, it is running at such a high speed, there is little room for improvement	There are possibilites for automating the processes that are still manual in the factory, or introduce a co-bot. For the trimming process, there is little improvement potential apart from optimizing the trimming machine further	Maintain				#DIV/0!	#DIV/0!	1,6	###	###	###	###	282	#DIV/0!	#DIV/0!
2,4	Reduce task repetition	1	It is not prioritized as much because there is no escaping task repetition in this type of work, and looking at the trimming process it is automated anyways	76	The trimming process is automated, no repetitiveness for manual workers. For other processes, it has been discussed to introduce a co-bot to vary the repetitive work somewhat for manual workers.	Not considered	Non-priority				#DIV/0!	#DIV/0!	0,8	###	###	###	###	177	#DIV/0!	#DIV/0!
2,5	Reduce susceptibility to pollutions from machinery waste products	3	Naturally important in this line of work	90	Since the trimming process is automated, it does not require much human contact, in addition to it not really being hazardous anyway	Making the machine require even less human attention and interaction if possible	Maintain				#DIV/0!	#DIV/0!	2,7	###	###	###	###	393	#DIV/0!	#DIV/0!
2,6	Reduce task difficulty in the sence of required force	1	Not really relevant as most of the manual work requires little physical force, apart from maybe some operational work done by caretakers. For the trimming process.	80	The trimming process is automated, but can require physical work if it potentially breaks down	Further reduce risk of machine defects	Non-priority				#DIV/0!	#DIV/0!	0,8	###	###	###	###	181	#DIV/0!	#DIV/0!
2,7	Promote preventive interventions in health, healthy environments and the adoption of healthy lifestyle habits	2	It is imortant that the workers have the health to actually work, but it is not only up to the company	70	The factory provides some services for the workers for them to be as healthy as possible, as well as a healthy environment and high-quality cantine	The company can encourage adoption of a healthy lifestyle to a larger degree by having more social gatherings that include enhancing health benefits	Maintain				#DIV/0!	#DIV/0!	1,4	###	###	###	###	272	#DIV/0!	#DIV/0!
2,8	Reduce factors likely to cause mental health issues	3	It is important that the workers have the mental health to work	80	Same as above, limiting the pressure of workers, allowing workers to take breaks when they need it	The company can provide more services for workers, like better access, discounts or advisement on psychologists, mental health worker, etc.	Maintain				#DIV/0!	#DIV/0!	2,4	###	###	###	###	383	#DIV/0!	#DIV/0!
2,9	Reduce any other irritants	3	All aspects of workers health and environment are generally important	80	For all things considering "health": There is always room for improvement with better solution for packing and driving the fish. Can add even more automation, reducing lifting and moving of fish which is what the factory does the most. The more machines you have the less work afterwards.	The company can for instance add a private "chill zone" for workers that need relaxation	Maintain				#DIV/0!	#DIV/0!	2,4	###	###	###	###	383	#DIV/0!	#DIV/0!
	Average weighting : Health	2,1	Weighted performance : Health	79 %																
3	**Safety**																			
3,1	Create a feeling of security	3	Security is obviously a high priority	90	The company keeps furniture updated, clean and safe. Also looking at safety of work: Keeping the job: especially important now with the new ground rent tax rules possibly leading to employees in the filet department loosing their jobs first: now, no new contracts are being made as it is unknown what effect this will have. No new contracts until oct 2023.	Always small rooms for improvement	Maintain				#DIV/0!	#DIV/0!	2,7	###	###	###	###	393	#DIV/0!	#DIV/0!
3,2	Ensure effective safety	3	Safety is obviously a high priority	90	Employees feel obvious safety, see above	Always small rooms for improvement	Maintain				#DIV/0!	#DIV/0!	2,7	###	###	###	###	393	#DIV/0!	#DIV/0!
3,3	Provide basic safety education	3	The factory requires workers that know what they do	100	Every employee gets basic training and education for what they are supposed to do, as well as EHS courses	No potential	Maintain				#DIV/0!	#DIV/0!	3	###	###	###	###	403	#DIV/0!	#DIV/0!
	Average weighting : Safety	3,0	Weighted performance : Security	93 %																
4	**Education**																			
4,1	Ensure an easy to work equipment	3	It is important that the equipment does not require extremely specific skills	90	The trimming process is fully automated and easy to learn. The company uses the same manufacturer all over the factory, simplifying things	Always room for simplifying further, or reducing risk of defects that can create hard tasks for caretakers	Maintain				#DIV/0!	#DIV/0!	2,7	###	###	###	###	393	#DIV/0!	#DIV/0!
4,2	Ensure a noncomplicated design process for manufacturing the equipment	2	Hard to consider, more up to manufacturer	80	A specific goal for the process is set	Not considered	Maintain				#DIV/0!	#DIV/0!	1,6	###	###	###	###	282	#DIV/0!	#DIV/0!
	Average weighting : Training	2,5	Weighted performance : Education	86 %																
5	**Work environment**																			
5,1	Reduce noise pollution	3	A big factory with a lot of export and traffic related to it, obviously produces a lot of noise that should be minimized	85	Noise inside the factory are not necessarily a treat to health or environment, but sounds outside can impact environment, which can possibly be reduced	Some loud noises from machines can be reduced	Maintain				#DIV/0!	#DIV/0!	2,6	###	###	###	###	388	#DIV/0!	#DIV/0!
5,2	Provide proper thermal conditions	3	It is important to maintain a high comfort for the workers	95	Ventilation and optimizition of roomtemperature is considered to a high degree	No specific potential for improvement	Maintain				#DIV/0!	#DIV/0!	2,9	###	###	###	###	398	#DIV/0!	#DIV/0!
5,3	Provide a proper lightening condition	3	It is important to maintain a high comfort for the workers	95	Optimization of lightning is considered to a high degree	No specific potential for improvement	Maintain				#DIV/0!	#DIV/0!	2,9	###	###	###	###	398	#DIV/0!	#DIV/0!
	Average weighting : Work environment	3,0	Weigthed performance : Human settlements	92 %																
	Average weighting : Social dimension	**2,6**	**Weighted performance : Social dimension**	**87 %**																

A- SDAG tool: Processor

ECONOMIC DIMENSION: Seeks to address the material needs and financial empowerment of individuals and communities.

Themes / Goals		Weighting	Justification for weighting	Assessment	Actions planned or already implemented	Opportunities for improvement	Priority
1	**Responsible production**						
1.1	Producing quality goods and services	3	The main goal of the company	100	Everyhting the company does is done with this in mind	Not relevant	Maintain
1.2	Ensure a time-efficient processing	3	The secondary main goal of the company	80	Not much to comment on the economic part. The focus is on bring good quality products while beeing time efficient. The quality must be good to sell and the volume must be great enough to ensure cash back.	Including more automation or even more high-technology equipment and processes will add efficieny	Maintain
1.3	Ensure adequation between needs and the goods and services produced	3	No comment	90	No comment	No comment	Maintain
1.4	Promoting eco design from a product life cycle perspective	2	No comment	88	No comment	No comment	Maintain
1.5	Promote sustainable industrialization	3	No comment	90	No comment	No comment	Maintain
1.6	Implement extended producer responsibility	3	No comment	80	No comment	No comment	Maintain
	Average weighting : Responsible production	2,8	Weighted performance : Responsible production	88 %			
2	**Economic viability**						
2.1	To ensure economic viability	3	The company always works towards ways of ensuring income and adapting to trends and risks than can affect economically	100	A lot of the money earned is spent on the company itself. A lot of capital earned is used on enlarging or improving what already is part of company, both offshore and onshore. Millions have been invested to be up to date on all trends.	Not relevant	Maintain
2.2	To ensure a minimum additional capital and operation cost	2	Additonal costs can come at any time due to multiple reasons	80	The company has a clear economic plan but by using resources to research and test out new ideas, there are always risks involved that not necessarily can be minimized. Not all co-operation processes turn out working, eventually leading to additional costs	Avoid taking too high financial risk risks	Maintain
2.3	To ensure a high profit margin	3	The company always works towards ways of ensuring income and adapting to trends and risks than can affect economically	100	See 2.1	Not relevant	Maintain
2.4	To limit the financial risks	3	The company must always assess all risks involved to ensure economic viability	90	The company has a clear economic plan and fincancial statements to follow. New projects are analyzed properly before exploring them physically	No further comments	Maintain
2.5	To limit the return on capital	2	No comment	80	No comment	No comment	Maintain
	Average weighting : Economic viability	2,6	Weighted performance : Economic viability	92 %			
3	**Work**						
3.1	To enhance job creation	2	The job is attractive for the locals as well as interests from far away through the company being "ahead" in many aspects	90	Historically, the job was for those who lived nearby and did not know what else to do. Today, it is more known to be a stable line of work, ensuring safety. Being up to date on trends can enhance interest and creation as well	Little room for improvement as the company's work in society and elsewhere creates no need to advertise jobs further.	Maintain
	Average weighting : Work	2,0	Weighted performance : Work	90 %			
4	**Energy**						
4.1	To reduce energy consumption	3	Somewhat answered in the environment aspect	90	See environment aspect	Not relevant	Maintain
4.2	To plan a wise use of energy	3	Keeping the energy usage to a degree where it wont affect the company in a negative way econominically is very important	90	The company spends energy in a wise way with its automation, assembly line and quick processes	As mentioned before, there is room for improvement in reducing energy usage by turning off lights or machines when not in use or the short periods inbetween shifts	Maintain
	Average weighting : Energy	3,0	Weighted performance : Énergie	90 %			

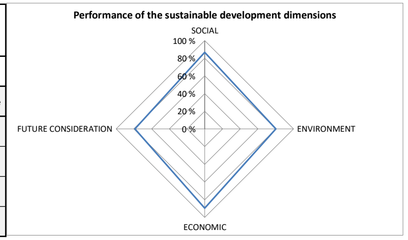
FUTURE CONSIDERATION DIMENSION: Seeks to address democracy and transparency needs, and the need for effective, digitalized innovations.

								Data quality index												
Themes	Goals	Weighting	Justification for weighting	Assessment	Actions planned or already implemented	Opportunities for improvement	Priority	Correlation	Status	Reliability	Data quality	Data needs	Note 1	Note 2	Note 3	Note 4	Note 5	Priority	Data	Data collection
1	**Innovation**																			
1.1	To increase innovation potential and diversify options in equipment design	3	The company has a big interest in being the best in the industry, to be attractive also for others than themselves	80	The company takes part in research projects and also has some employees working within R&D.	Further research and innovation enhancement	Maintain				#DIV/0!	#DIV/0!	2,4	###	###	###	###	383	#DIV/0!	#DIV/0!
1.2	To promote research and development involvement in design process	3	As the company has own employees working in R&D, this is very important for them. This also involves the design process.	80	The company always takes part by telling how they want it to be and how things are. Looking at machine development, they can often take part by demanding comfort, hygiene or accessability.	Even further involvement in collaboration with designers and the manufacturer	Maintain				#DIV/0!	#DIV/0!	2,4	###	###	###	###	383	#DIV/0!	#DIV/0!
1.3	To have a more automated operation	3	Very attractive. Slaughter department is almost fully automated, it is wishful to do the same to the filleting department	85	There are new product for laying, moving and packaging fish that could be attractive for the factory if they work. An attractive thought are co-bots that can work next to manual workers for example when packaging fillets.	Add more automation as soon as there are products relevant for these processes. Be involved in the creation of these potential products	Maintain				#DIV/0!	#DIV/0!	2,6	###	###	###	###	388	#DIV/0!	#DIV/0!
1.4	To enhance equipment versatility	3	Most product all specialized for a product, but the factory itself works also as one holistic process with all processes connected together	70	There is no way of making one equipment more versatile as it is so specialized, but there is constant development in how to connect all processes within the filleting department in order to optimize equipment	Optimize the co-operation between all factory processes	Maintain				#DIV/0!	#DIV/0!	2,1	###	###	###	###	373	#DIV/0!	#DIV/0!
1.5	To consider future trends in food industry	3	The company is keen to always adapt to how the world wants thing to be	80	The company identifies at any time what the market asks for. Sometimes smaller portions, and now it seems as though the market want product that demand the least amount of work (i.e. sous vide?). Depends on the exporter and planning as well.	No specific opportunities: further adaption through R&D and being involved in conferenece for future food technology	Maintain				#DIV/0!	#DIV/0!	2,4	###	###	###	###	383	#DIV/0!	#DIV/0!
1.6	To adapt the design with industry 4.0, Internet of things, smart control of the process, machine learning	2	It is unsure whether there is an actual need for the company to become this smart in very near future, but eventually, yes	60	There is already discussion around implementing this "smartness" but it is unsure when it will be relevant	Add smartness to the already existing automatic tech	Maintain				#DIV/0!	#DIV/0!	1,2	###	###	###	###	262	#DIV/0!	#DIV/0!
1.7	To manage risks associated with new technologies	3	The company are willing to be, and have been taking risks and being the guinea pig. Sometimes it works, sometimes not (then you will hear about it in 10 years!)	80	The company has already participated in a lot of projects that have ended up not being fulfilled or useful, that is a risk the company is willing to take. They find some projects they are willing to spend money on, and this will always involve risks, as investors always will wish for money back eventually. Just upgrading the factory has shown that the company are aware of, and identify the risks of new technologies.	No way of improving this goal, risks are always involved even though an analyze can be made to identify them beforehand, they need to be physically tested	Maintain				#DIV/0!	#DIV/0!	2,4	###	###	###	###	383	#DIV/0!	#DIV/0!
	Average weighting : Innovation	2,9	Weighted performance : Innovation	77 %																
2	**Risk management and resilience**																			
2.1	To identify risks	3	Obviously it is important to know what risks are involved in all processes and part of the processes	70	Risk is assessed on all levels, cyber/hacking, considering market, resources in the world. Multiple people in the company work on this (the employee is a bit unsure)	Employee is unsure, but believes are risks are analyzed and assessed on every level already. Can always improve further since most projects have high risks	Maintain				#DIV/0!	#DIV/0!	2,1	###	###	###	###	373	#DIV/0!	#DIV/0!
2.2	To apply the principle of prevention	3	It is important to use principle of prevention to avoid problems	90	Risk is assessed on all levels within the factory (HAZOP). It is always evaluated what implies high risk and what implies low.	No further comments	Maintain				#DIV/0!	#DIV/0!	2,7	###	###	###	###	393	#DIV/0!	#DIV/0!
2.3	To consider the perception of risk	3	No comment, all risk management is important	80	No comment	No comment	Maintain				#DIV/0!	#DIV/0!	2,4	###	###	###	###	383	#DIV/0!	#DIV/0!
2.4	To promote an equitable distribution of risks	3	It has to be clear who takes the blame when the company is involved in "risky business" with multiple stakeholders	70	There is a collaboration between the company and exporters on who will take the risks. If the company takes part in projects where new things are tested, it is identified and distributed fairly who will take the potential risks.	There can for instance be further training for managers to respond to a crisis situation.	Maintain				#DIV/0!	#DIV/0!	2,1	###	###	###	###	373	#DIV/0!	#DIV/0!
2.5	To provide for adaptations to changes	3	The company is keen to follow trends at any time, also the trend of global changes, like climate	80	Something that is done constantly on all levels, as already discussed	No further comments	Maintain				#DIV/0!	#DIV/0!	2,4	###	###	###	###	383	#DIV/0!	#DIV/0!
	Average weighting : Risk management and resilience	3,0	Weighted performance : Risk management and resilience	78 %																
3	**Data digitalization**																			
3.1	To monitor food processing during equipment operation	2	A somewhat high priority for the fish to be of highest possible quality, but to do so digitally is not the only way of ensuring this.	70	It is a must to have this data for controls. However, it is constantly unsure if the data is optimized, there might always be room for potential. Apart from this, the fish are also taken photos of in both the gutting process and in the packages so that it is always possible to track back the fish. All fish have IDs. Many controls. Many numbers on waste, trying to minimize these. Always a lot of data going around. Currently working on digitalizing quality data and quality systems, as there are still a lot of paper solutions when it comes to this, creating a lot of work right now: Will probably improve a lot the next year. Still a high score since the company uses a lot of process built upon data; for instance removing fish when it provides "wrong" data	See actions planned	Maintain				#DIV/0!	#DIV/0!	1,4	###	###	###	###	272	#DIV/0!	#DIV/0!
6.2	To digitalize food processing data for sharing and transparency	3	The company believes in honesty and transparancy to optimize the exchange of information, so it is highly prioritized	100	It is demanded from multiple approval firms the company collaborates with that it is possible to track back fish through its whole life cycle, and this is possible within the company. This must be possible within four hours after beeing asked, but is not a problem with all data being available from start to end of life. All data is not open for anyone to see at any time since it is enormously large, but: if searched for, it can easily be found.	Not relevant	Maintain				#DIV/0!	#DIV/0!	3	###	###	###	###	403	#DIV/0!	#DIV/0!
	Average weighting : Data digitalization	2,5	Weighted performance : Information	88 %																
	Average weighting : Future consideration dimension	**2,9**	**Weighted performance : Future consideration dimension**	**79 %**																

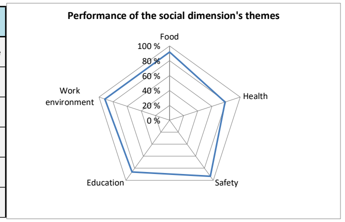
A- SDAG tool: Processor

A- SDAG tool: Processor

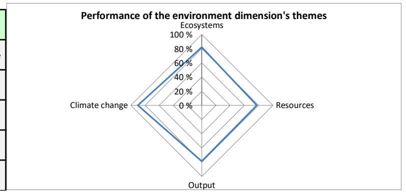
Project :	Sustainability in trimming machine	
Date :	15. Oct 2022	
DIMENSION	Average weighting	Average performance
SOCIAL	2,6	87 %
ENVIRONMENT	1,8	80 %
ECONOMIC	2,7	90 %
FUTURE CONSIDERATION	2,9	79 %



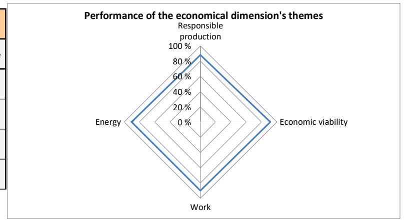
SOCIAL DIMENSION		
THEME	Average weighting	Average performance
Food	3,0	92 %
Health	2,1	79 %
Safety	3,0	93 %
Education	2,5	86 %
Work environment	3,0	92 %



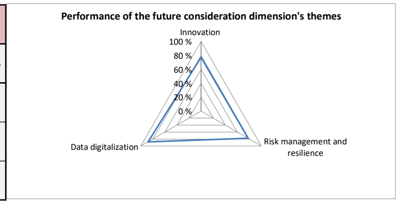
ENVIRONMENT DIMENSION		
THEME	Average weighting	Average performance
Ecosystems	2,5	82 %
Resources	2,3	78 %
Output	1,7	79 %
Climate change	1,2	90 %



ECONOMICAL DIMENSION		
THEME	Average weighting	Average performance
Responsible production	2,8	88 %
Economic viability	2,6	92 %
Work	2,0	90 %
Energy	3,0	90 %



FUTURE CONSIDERATION DIMENSION		
THEME	Average weighting	Average performance
Innovation	2,9	77 %
Risk management and resilience	3,0	78 %
Data digitalization	2,5	88 %



B- SDAG tool: Manufacturer

ENVIRONMENT DIMENSION: Seeks to address the need for a quality natural environment and for sustainable resources.

Themes	Goals	Weighting	Justification for weighting	Assessment	Actions planned or already implemented	Opportunities for improvement	Priority
1 Ecosystems							
1.1	Minimize yield loss of main food product from raw material during processing	3	Fish farming and harvesting have obvious correlations with ecology, sea-ecosystem, capacity, etc.	90	Should be 100% for a new concept. This is a problem for all clients, yield loss happens for most processing equipment, but should be avoided, why can it not be avodied?	Avoid any yield loss.	Maintain
	Facilitate optimal utilization of rest raw material for human or animal consumption	3	It is essential to follow regulations. While one of the main goals of the manufacturer is for the equipment users to avoid rest raw material, it is also important to have solutions to optimize utilization just in case.	90	The company follows all the regulations required for rest raw material. See above	Avoid floor fish completely. But it is often not up to the manufacturer. (note that the manufacturer actually gave a score of 100 on both goals).	Maintain
	Average weighting : Ecosystems	**3,0**	**Weighted performance : Ecosystems**	**90 %**			
2 Resources							
2,1	Minimize energy consumption	2	According to the manufacturer, energy usage is never a priority of the client. Energy will be one of the things the clients consume the most as they have a large, automated, generally high tech. factory. It is somewhat conisdered by this specific manufacturer, but the electricity spent is only considered "a drop in the ocean" as part of the entire industry.	60	Improvement potential of maybe 10% electricty saved for engines in the factory, estimated to be probably only 20 kW for the small conveyor belt motors needded	Prioritize energy usage to a higher degree	Maintain
2,2	Minimize food grade water consumption	2	Depends very much on the client, because some pay a lot for water, while others not	60	None really, as it is customer-dependant. For the clients that want to minimize water usage, it is prioritized, for others, not so much	Always prioritize minimization of water consumption	Maintain
2,3	Efficient and easy cleanability	3	Absolutely essential	100	One of the main priorities of the manufacturer and very resource-demanding. Non-clean equipment will immediately affect the processed food.	Not relevant	Maintain
2,4	Easy-to-dismantle for frequent component replacement, e.g. conveyors	3	Very important	100	Also considered very important because it will affect the cleanability and maintenance, see above.	Not relevant	Maintain
2,5	Weight reduction: reducing used materials for manufacturing	3	Very important. A balance between cleanability-friendliness	80	The manufacturer recently made something called a "hygiene-transporter", where many extra kg of steel is used, but it is much easier to clean. So, usually cleanability is prioritized over steel usage, but it is still important	Not much. Make a clear analysis of priorities of each customer in regards of weight and cleanability demands. Possibly look at other materials (but this manufacturer mainly uses stainless steel and food grade plastic.	Maintain
2,6	Choose low-impact body materials	2	Are doing some analyses on this, but should be prioritized	60	The variance in materials used by the manufacturer is not very widespread. Mainly stainless steel and food grade plastic. They are known to be somewhat low-impact, but figuring this out/analyzing their impacts is not something prioritized by the manufacturer	More analyses	Maintain
2,7	Choose easy-to-clean materials	3	Only steel (stainless), food grade plastics, water: Essential	100	Again, cleanability is essential, and the materials chosen are therefor very relevant	Not relevant	Maintain
2,8	Use recyclable materials	3	All the materials used are recyclable in their own ways, and it is prioritized	100	Materials known to be recycleable are chosen.	Manufacturer has given this an assessment of 100, but given the fact that food grade water consumption is not assessed well, maybe it should be less, as all water is not "recycled".	Maintain
2,9	Use durable materials	3	Important	100	Not many materials, the ones chosen are durable. If anything would fail or be broken, easy dismantling is prioritized - but it happens rarely	Little improvement opportunites given that the factory almost rather has issues with things lasting "too long".	
2,10	Plan for the prudent use of resources	3	Important	100	See 2.8	Not considered	Maintain
2,11	Optimize resources that are at the end of their life	2	Not considered because no resources with short lifetimes are used. Actually, the company struggles more with the fact that the 40 year old equipment never "dies".	83	Not considered relevant	Not considered	Maintain
	Average weighting : Resources	**2,6**	**Weighted performance : Resources**	**68 %**			
3 Output							
3,1	Identify liquid, solid and gaseous outputs and the impacts on the environment		Output is not considered because it is up to the producer, not the manufacturer				
3,2	Reduce need for washing agents and disinfectant		Depends somewhat on design, which is considered in the design for cleanability goal				
3,3	Minimize noise emission		Design for emissions is considered within the social dimension				
3,4	Minimize odor emission						
3,5	Minimize liquid effluents						
3,6	Minimize solid wastes (sludge, used chemicals ...)						
3,7	Minimize the negative impacts of outputs						
3,8	Manage hazardous waste properly						
	Average weighting : Output	**0,0**	**Weighted performance : Output**	**0 %**			
4 Climate change							
4,1	Quantify greenhouse gas emissions	2	The manufacturer is currently in the final phase of an Eco-Lighthouse certification (miljøfyrtårn), and emphasizes emissions. However, they dont really produce emissions apart from some related to transport (like the producer)	90	Not considered	Not considered	Maintain
4,2	Reduce GHG emissions	2	Not considered relevant	90	Not considered	Not considered	Maintain
4,3	Compensate for greenhouse gas emissions	2	Not considered relevant	90	Not considered	Not considered	Maintain
4,4	Reduce Atmospheric emissions (exhausted gases, steam, ...)	2	Can be somewhat relevant	90	Most technology in the factory does not produce emissions	Electrify all transport related to the factory	Maintain
4,5	Plan for adaptation measures to respond to the new climate reality	2	Not considered relevant	90	Not considered	Not considered	Maintain
	Average weighting : Climate change	2,0	Weighted performance : Climate change	90 %			
	Average weighting : Ecological dimension	**2,5**	**Weighted performance : Ecological dimension**	**76 %**			

B- SDAG tool: Manufacturer

SOCIAL DIMENSION: Seeks to address social needs, individual and collective aspirations, health and well-being needs, and quality of life needs.

Themes	Goals	Weighting	Justification for weighting	Assessment	Actions planned or already implemented	Opportunities for improvement	Priority
1	**Food**						
1,1	Ensure food safety during processing	3	"Self explanatory" in the food industry. This is what makes their living, so there is a lot of pressure and focus within food safety and security.	100	Manufacturer is unsure if it is relevant apart from the cleanability and use of materials. They will obviously not use any random type of plastic, but have chosen materials they know are safe and secure in the food industry.	Not considered	Maintain
1,2	Ensure food security	3	"Self explanatory" in the food industry	100	Related to the design for cleanability, which is very much prioritized	Not considered	Maintain
1,3	Align processing impact on food quality with consumer preferences	3	"Self explanatory" in the food industry	100	See above	Not considered	Maintain
	Average weighting : Food	3,0	Weighted performance : Food	100 %			
2	**Health**						
2,1	Provide an ergonomic condition for employees	3	For the workers that utilize the equipment, the work can be physically exhausting or demanding, so ergonomics are very important	100	All design is done to ease work for employees of the factory. All parts of design are accessible, easy to clean, easy to dismantle, easy to learn, easy to use, etc.	Not considered	Maintain
2,2	Consider gender status in ergonomic design	2	Ergonomic design in terms of gender status because all products are universal for both genders.	50		Keep in mind that the manufacturer assessed this 100% but	
2,3	Reduce task duration	3	It is natural that the process has tasks that can take a long time	100	Manufacturer has little comments on this and assesses the 100% to an ideal product, not a specific one. Not all processes are autonomous yet, and have improvement areas in adding automation - thereby reducing task duration	There are possibilites for automating all potential processesing equipments made	Maintain
2,4	Reduce task repetition	3	It is natural that things are constantly repeated in fish-factories	100	If processing equipment are made automative so that there is repetitiveness for manual workers, they are perfect. A co-bot could also be added to some processes, to reduce repetitiveness. Remember, the assessment here is for an ideal equipment	Not considered	Maintain
2,5	Reduce susceptibility to pollutions from machinery waste products	2	Not considered relevant, as no equipment really has pollution	50	The low assessment rating is given because it is not considered relevant. If they were to produce machines that produce pollutions, it would absolutely be prioritized, so keep in mind the assessment rating can be deceptive.	Making equipment require even less human attention and interaction if possible	Act
2,6	Reduce task difficulty in the sence of required force	3	Not really relevant as most of the manual work requires little physical force, apart from maybe some operational work done by caretakers.	100	The trimming process is automated, but can require physical work if it potentially breaks down	Further reduce risk of machine defects	Maintain
2,9	Reduce any other irritants	3	All aspects of workers health and environment are generally important. Specifically, noise pollution can affect physical health.	80	For all things considering "health": There is always room for improvement with better solutions. Can add even more automation, reducing lifting and moving of fish. The more machines you have the less work afterwards. Manufacturer specifically aims to reduce noise irritants because these are considered the most relevant health issues	Reduce all noise emissions to acceptable levels that are not affecting workers health. Also prioritize other possible irritants.	Maintain
	Average weighting : Health	2,7	Weighted performance : Health	81 %			
3	**Safety**						
3,1	Create a feeling of security	3	Security is obviously a high priority	100	No specific comments	Not considered relevant	Maintain
3,2	Ensure effective safety	3	Safety is obviously a high priority	100	No specific comments	Not considered relevant	Maintain
3,3	Provide basic safety education	3	The factory requires workers that know what they do	100	No specific comments	Not considered relevant	Maintain
	Average weighting : Safety	3,0	Weighted performance : Security	100 %			
4	**User-friendly**						
4,1	Ensure an easy to work equipment	3	Like cleanability, durability, and other simplifying, it is important that the eqipment is easy to utilize for the potential factory workers	80	None specific, design for accessibility is prioritized, but it is not always simple to fullfill	Always room for simplifying further, or reducing risk of defects that can create hard tasks for caretakers	Maintain
4,2	Ensure a noncomplicated design process for manufacturing the equipment	2	Simplifying the manufacturing saves time, material, etc.	60	The design process of most equipments are simply not "noncomplicated" because they are advanced.	No further comments	Maintain
	Average weighting : Training	2,5	Weighted performance : Education	72 %			
5	**Work environment**						
5,1	Reduce noise pollution	3	A big factory with a lot of export and traffic related to it, obviously produces a lot of noise that should be minimized	80	Noise inside the factory are not necessarily a treat to health or environment, but sounds outside can impact environment, which can possibly be reduced	Some loud noises from machines can be reduced	Maintain
	Average weighting : Work environment	3,0	Weigthed performance : Human settlements	80 %			
	Average weighting : Social dimension	**2,8**	**Weighted performance : Social dimension**	**88 %**			

B- SDAG tool: Manufacturer

ECONOMIC DIMENSION: Seeks to address the material needs and financial empowerment of individuals and communities.

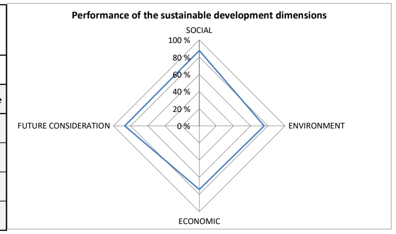
Themes Goals		Weighting	Justification for weighting	Assessment	Actions planned or already implemented	Opportunities for improvement	Priority
1	**Responsible production**						
1.1	Producing quality goods and services	3	The main goal of all fish processers, so therefor also the manufacturer of their equipment	100	Mainly everyhting the company does is done with this in mind	Not relevant	Maintain
1.2	Ensure a time-efficient and immediate processing	3	The secondary main goal of the company	100	Not much to comment on the economic part. The focus of the fish processor is on bring good quality products while beeing time efficient. The quality must be good to sell and the volume must be great enough to ensure cash back. Therefor, this is also the priority of the equipment manufacturer.	Including more automation or even more high-technology equipment and processes will add efficieny and therefor market attractiveness	Maintain
1,3	Ensure a continuous line processing	2	Essential. Manufacturer is always searching for potential bottlenecs, improving there, finding another, continuosly improving.	100	Refusing waiting fish, or anything that could potentially affect the quality of the products and time efficiency.	Not relevant	Maintain
1,4	Easy and predictive maintenance	2	Simply very important.	100	As mentioned earlier in the environment dimension.	No comment	Maintain
1.5	Ensure adequation between needs and the goods and services produced	2	Simply very important.	100	No comment	No comment	Maintain
1.6	Promoting eco design from a product life cycle perspective	2	Simply very important.	100	Manufacturer does a lot of product life cycle assessments, to trace potential problems and for easy maintenance	No comment	Maintain
1.7	Promote sustainable industrialization	2	As above	100	No comment	No comment	Maintain
	Average weighting : Responsible production	**2,3**	Weighted performance : Responsible production	**75 %**			
2	**Economic viability**						
2.1	To ensure economic viability		None of the economic viability goals are considered by the manufacturer because they are mostly aimed at the producer of the fish products. However, if they are targeted at the manufacturer, they are all assessed 3 and 100%.		A lot of the money earned is spent on the company itself. A lot of capital earned is used on enlarging or improving what already is part of company. According to the manufacturer, they do a lot of product development.	Not relevant	
2.2	To ensure a minimum additional capital and operation cost				The company has a clear economic plan but by using resources to research and test out new ideas, there are always risks involved that not necessarily can be minimized.	Avoid taking too high financial risk risks	
2.3	To ensure a high profit margin				See 2.1	Not relevant	
2.4	To limit the financial risks				The company has a clear economic plan and fincancial statements to follow. New projects are analyzed properly before exploring them physically.	No further comments	
2.5	To adhere to limiting +D17:D21the return on capital				No comment	No comment	
	Average weighting : Economic viability	**0,0**	Weighted performance : Economic viability	**0 %**			
3	**Work**						
3.1	To enhance job creation	2	Not really considered	75	Not considered	Little room for improvement as the company's work in society and elsewhere creates no need to advertise jobs further.	Maintain
	Average weighting : Work	**2,0**	Weighted performance : Work	**75 %**			
4	**Energy**						
4.1	To reduce energy consumption and the respective cost	2	Somewhat answered in the environment aspect, not considered further	70	See environment aspect	Not relevant	Maintain
4.2	To plan a wise use of energy	2	Keeping the energy usage to a degree where it wont affect the company in a negative way economically is very important, but the manufacturer has not considered this themselves because they are very rarely asked by their clients to consider energy usage. For the manufacturing company themselves, they have only some improvement areas in reducing energy usage, so it is not prioritized	70	The company spends energy in a wise way with its simply and quick parallell processes.	There is probably room for improvement in reducing energy usage by turning off lights or machines when not in use or the short periods inbetween shifts. It is unknown what the manufacturer things of this, or what the shifts are like at the manufacturing company.	Maintain
	Average weighting : Energy	**2,0**	Weighted performance : Énergie	**70 %**			

B- SDAG tool: Manufacturer

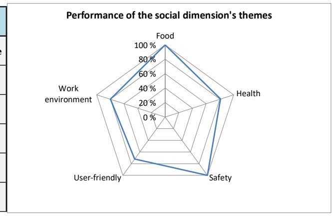
								Data quality index													
FUTURE CONSIDERATION DIMENSION: Seeks to address democracy and transparency needs, and the need for effective, digitalized innovations.																					
Themes / Goals		**Weighting**	**Justification for weighting**	**Assessment**	**Actions planned or already implemented**	**Opportunities for improvement**	**Priority**	**Correlation**	**Status**	**Reliability**	**Data quality**	**Data needs**	**Note 1**	**Note 2**	**Note 3**	**Note 4**	**Note 5**	**Priority**	**Data**	**Data collection**	
1 Innovation																					
1.1	To increase innovation potential and diversify options in equipment design	2	The company has a big interest in being the best in the industry, to be attractive also for others than themselves. The company feels like they work with product development everyday	100	It is unknown if the manufacturer has an own specific R&D department, but it is said that the workers constnatly work with product development and research	Further research and innovation enhancement	Maintain				#DIV/0!	#DIV/0!	2	###	###	###	###	302	#DIV/0!	#DIV/0!	
1.2	To promote research and development involvement in design process	3	As long as the company has improvement potential in adding automation etc, this is very important for them	100	Good collaborations with stakeholders, both suppliers and customers.	Even further involvement in collaborations and stronger prioritization of adding new technologies	Maintain				#DIV/0!	#DIV/0!	3	###	###	###	###	403	#DIV/0!	#DIV/0!	
1.3	To have a more automated operation and food production	3	Very attractive	100	There are new products for laying, moving and packaging fish that could be attractive for factories, and the manufacturer must remain attractive in the market. This manufacturer mainly makes simple products and conveyors, not very many "machines", so it somewhat hard to consider	Add more automation as soon as there are new products. Be involved in the creation of these potential new products	Maintain				#DIV/0!	#DIV/0!	3	###	###	###	###	403	#DIV/0!	#DIV/0!	
1,4	To develop autonomous robotic washing solutions	1	It is not prioritized currently. But they have heard of the idea and think it would be "absolutely amazing" if it could be used, because they spend an obscene amount of resoruces on washing and cleaning agents	100	Ideally, assessed 100%, currently not prioritized. Heard of, but would be too large of an investment	Prioritize and apply autonomous solutions like these	Non-priority				#DIV/0!	#DIV/0!	1	###	###	###	###	201	#DIV/0!	#DIV/0!	
1.6	To enhance equipment versatility	2	Most product are specialized for a process, but most processing factories works also as one holistic unit with all processes connected together. Therefor, manufacturing versatile equipment is highly prioritized	100	There are few ways of making one equipment more versatile as it is so specialized, but there is constant development in how to connect all processes to optimize equipment. This manufacturer makes mainly the "simple" parts of the factory like tables and conveyors that acutally do this work; connect them, and they are made very versatile, fitting in everywhere	Not considered	Maintain				#DIV/0!	#DIV/0!	2	###	###	###	###	302	#DIV/0!	#DIV/0!	
1.7	To optimize cooperation between successive processes	3	See the continuos line processing-goal	100	See 1.3 in the economic dimension	Not considered	Maintain				#DIV/0!	#DIV/0!	3	###	###	###	###	403	#DIV/0!	#DIV/0!	
1.8	To consider future trends in food industry	2	The company is keen to always adapt to how the world wants thing to be	100	The company identifies at any time what the market asks for. Depends on the exporter and planning as well.	No specific opportunities: further adaption through R&D and being involved in conferenece for future food technology	Maintain				#DIV/0!	#DIV/0!	2	###	###	###	###	302	#DIV/0!	#DIV/0!	
1.9	To adapt the design with industry 4.0, Internet of things, smart control of the process, machine learning	3	It is unsure whether there is an actual need for the company to become this smart in very near future, but eventually, yes	100	There is already discussion around implementing this "smartness" but it is unsure when it will be relevant	Add smartness to the already existing automatic tech	Maintain				#DIV/0!	#DIV/0!	3	###	###	###	###	403	#DIV/0!	#DIV/0!	
Average weighting : Innovation		2,4	Weighted performance : Innovation	100 %																	
2 Risk management and resilience																					
2.1	To identify risks at different operation levels	2	Obviously it is important to know what risks are involved in all processes and part of the processes	50	A lot of improvement potential. According to the manufacturer, the risks are not identified a lot, "sometimes we just throw on a sticker". Risks are somwhat analyzed and assessed on every level already, but not thouroughly.	Can improve a lot since most projects have high risks	Act				#DIV/0!	#DIV/0!	1	###	###	###	###	252	#DIV/0!	#DIV/0!	
2.2	To manage risks associated with new technologies	2	The company are willing to be, and have been taking risks. However, risks are not assesses thoroughly	50	No further comments apart from those in 2.1.	Little ways of improving this goal in terms of new projects, because risks are always involved even though an analysis can be made to identify them beforehand, they need to be physically tested. However, it is important that these risk analyses are actually done correctly.	Act				#DIV/0!	#DIV/0!	1	###	###	###	###	252	#DIV/0!	#DIV/0!	
2.3	To apply the principle of prevention	2	It is important to use principle of prevention to avoid problems	50	Risk is somewhat assessed within the factory (HAZOP), but again, not good enough.	No further comments	Act				#DIV/0!	#DIV/0!	1	###	###	###	###	252	#DIV/0!	#DIV/0!	
2.4	To have ease in controlling in case of FPE failure	3	It is easy to identify FPE failures	100	When equipment fails, the area that leads to failure is simple to identify by seeing what failure has occured	Not relevant	Maintain				#DIV/0!	#DIV/0!	3	###	###	###	###	403	#DIV/0!	#DIV/0!	
2.5	To promote an equitable distribution of risks	3	It has to be clear who takes the blame when the company is involved in "risky business" with multiple stakeholders	100	There is a collaboration between the company and exporters on who will take the risks. If the company takes part in projects where new things are tested, it is identified and distributed fairly who will take the potential risks.	The manufacturer says there are little projects where the risks involved are so large that this is relevant	Maintain				#DIV/0!	#DIV/0!	3	###	###	###	###	403	#DIV/0!	#DIV/0!	
2.6	To provide planning actions and consideration for adaptions to global changes	3	The company is keen to follow trends at any time, also the trend of global changes, like climate. "We are business cycle/conjuncture controlled and adaptable, we align ourselves with the fishing fleet".	100	Something that is done constantly on all levels	No further comments	Maintain				#DIV/0!	#DIV/0!	3	###	###	###	###	403	#DIV/0!	#DIV/0!	
Average weighting : Risk management and resilience		2,5	Weighted performance : Risk management and resilience	80 %																	
3 Data digitalization																					
3.1	To monitor food processing during equipment operation	2	A somewhat high priority for the fish to be of highest possible quality, but to do so digitally is not the only way of ensuring this. There is central risk control, and a couple of projects on this - but a generel need and desire for improvement - Should work more on this but simply no capacity.	50	It is a must to have this data for controls. However, for the manufacturer, there is little control, specifically withing data monitoring. There are currently a few projects on central-risks, but a need and a wish to improve further.	According to the manufacturer, there should be a bigger focus on imrpoving data digitalization, but they currently dont have the capacity to do so	Act				#DIV/0!	#DIV/0!	1	###	###	###	###	252	#DIV/0!	#DIV/0!	
3.2	To digitalize food processing data for smart production planning and control	2	The company believes in honesty and transparancy to optimize the exchange of information, so it is prioritized, but it is believed to be more important for the fish producer instead of the equipment manufacturer	50	No comments on what is already implemented in terms of digitalization of data, and it is also unsure what needs to be documented. Like with risks, there is a wish to improve in this area for easier controls.	No further comments	Act				#DIV/0!	#DIV/0!	1	###	###	###	###	252	#DIV/0!	#DIV/0!	
Average weighting : Data digitalization		2,0	Weighted performance : Information	50 %																	
Average weighting : Future consideration dimension		**2,4**	**Weighted performance : Future consideration dimension**	**87 %**																	

B- SDAG tool: Manufacturer

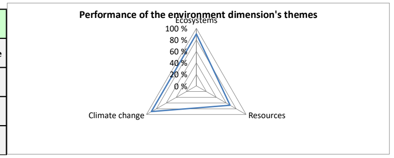
Project :	Sustainability in trimming machine	
Date :	15. Oct 2022	
DIMENSION	Average weighting	Average performance
SOCIAL	2,8	88 %
ENVIRONMENT	2,5	76 %
ECONOMIC	2,2	74 %
FUTURE CONSIDERATION	2,4	87 %



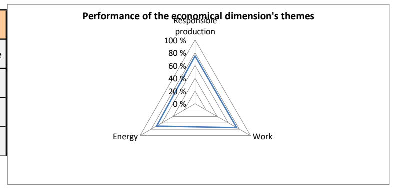
SOCIAL DIMENSION		
THEME	Average weighting	Average performance
Food	3,0	100 %
Health	2,7	81 %
Safety	3,0	100 %
User-friendly	2,5	72 %
Work environment	3,0	80 %



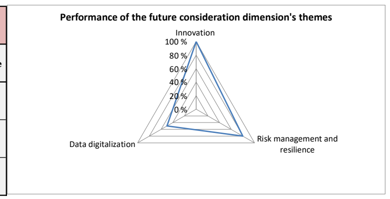
ENVIRONMENT DIMENSION		
THEME	Average weighting	Average performance
Ecosystems	3,0	90 %
Resources	2,6	68 %
Climate change	2,0	90 %



ECONOMICAL DIMENSION		
THEME	Average weighting	Average performance
Responsible production	2,3	75 %
Work	2,0	75 %
Energy	2,0	70 %



FUTURE CONSIDERATION DIMENSION		
THEME	Average weighting	Average performance
Innovation	2,4	100 %
Risk management and resilience	2,5	80 %
Data digitalization	2,0	50 %



C - Animations of Alternatives

The Lock System:

https://vimeo.com/829912585?share=copy

The Stamp System:

https://vimeo.com/829916918?share=copy

D- Comparison of Solution Alternatives

Nr.	Identified requirements	Functional solutions			
		Two-level Locks	Two parallel lock systems	Different sized pistons	3 stamp systems
1	**Produces quality goods in line with the hygienic regulations and food safety standards in the industry**	No reason to why it should not be	No reason to why it should not be	No reason to why it should not be	No reason to why it should not be
2	**Has a continuous line processing**	Yes, but piecemeal	Yes, with a streamline flow	Yes, but piecemeal	Yes, with a streamline flow
3	**Handles a significant number of fillets per time and is time efficient.**	Will be able to handle a lot of fish at once with different levels. Many motions that can take time	Can handle two batches of 25 continuously. Many motions that can take time	Can handle both larger and smaller batches. Consist of one main moving object	Can handle batches of 25 continuously. Consists of one main moving object
4	**Leakage control with CO_2 circulation (avoids emissions)**	Some valves. Locking mechanisms for each door making the locks and chamber airtight	Some more valves than one two-level lock system	A lot of valves. Locking mechanism for top and bottom part of stamp to create an airtight environment	Some more valves than when having two pistons
5	**The equipment provides a significant shelf-life extension of the fillets**	Yes, that is the aim of SGS	Yes, that is the aim of SGS	Yes, that is the aim of SGS	Yes, that is the aim of SGS
6	**Avoids yield losses of food**	Provides a closed environment. Be aware of the gaps between the conveyor belts	Provides a closed environment. Be aware of the gaps between the conveyor belts	Provides a closed environment. Be aware of the gaps between the conveyor belts	Provides a closed environment. Be aware of the gaps between the conveyor belts
7	**Has monitorable data**	Can be added. A lot of data to be monitored as there are three phases in the system	Can be added. A lot of data to be monitored as there are three phases in the system	Can be added. Perhaps easier to monitor due to all processes happening in the same area	Can be added. Perhaps easier to monitor due to all processes happening in the same area

8	**Has an easy-to-clean design**	Somewhat hard areas to reach. Corners should be hollow if possible. Long pipes should be avoided	Somewhat hard areas to reach. Corners should be hollow if possible. Long pipes should be avoided	Sharp edges and corners should be filleted. Long pipes should be avoided.	Sharp edges and corners should be filleted. Long pipes should be avoided.
9	**The energy usage is somewhat minimized**	Unknown, but has elevators. Circulation system can be very energy consuming	Unknown, but has additional conveyors. Circulation system can be very energy consuming	Unknown, but has multiple valves that need controlling and monitoring. Circulation system…	Unknown, but has additional valves and circulation systems
10	**The fillets inside the equipment are sorted nicely for the packaging step**	Yes, with a separator before the processing	Yes, with a separator before the processing	Yes, with a separator before the processing	Yes, with a separator before the processing
11	**Is in close proximity to packaging**	Easy to send the fillets directly to packaging. Little effect on desorption. However, there will be a queue	No queues other than the batch itself	Will have a queue	No queues other than the batch itself
12	**The equipment is versatile, can take multiple products of different temperatures and is adaptable to tray usage. Can be combined with sub-chilling.**	Should be adaptable to all products.	Should be adaptable to all products.	Should be adaptable to all products. Can most probably be combined with sub-chilling.	Should be adaptable to all products. Can most probably be combined with sub-chilling.
13	**Maintenance ease**	Many moving parts; gates, elevator, multiple belts. Circulation system demands extra attention.	Many moving parts; gates and multiple belts. +circulation system	One large moving object (x2), simple to maintain, but with many valves. +circulation system	One large moving object (x3), simple to maintain, but with many valves. +circulation system
14	**Reasonable space usage**	Long, slim and in-line. Can build upwards. Space usage in	Long, slim and in-line. Simple with two sets of the same	Is fit for in-line and can be added to already	Is fit for in-line and can be added to already

		lock can be optimized with logistics. Can possibly influence the solubility and therefor jet configuration	“small” systems.	existing conveyor belts. Is less “bulky”. Space usage inside pistons can be further optimized	existing conveyor belts. Is less “bulky”. Space usage inside pistons can be further optimized
11	**Universal belt usage**	Fits standard belt material, should be modular	Fits standard belt material, should be modular	Fits standard belt material, should be modular	Fits standard belt material, should be modular
?	**Is investment-friendly for the clients**	Unknown	Unknown	Unknown	Unknown
?	**Provides long-term financial benefits for the manufacturer**	Unknown	Unknown	Unknown	Unknown

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