

Concept exploration; Integrating atmospheric water generation systems onto spray drying process

Concept exploration of integrating atmospheric water generation systems onto spray drying process to capture the water in the residual air

Master's thesis in Product Development

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DEPARTMENT OF INDUSTRIAL AND MATERIALS SCIENCE

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Cover: The final concept in the thesis. This structure is to be installed in connection with the outlet air from a spray dryer. The concept consists of the components necessary for atmospheric water generation. The particular structure consists of the three different cubes with different functions connected in series and in turn eight of the three combined cubes are attached in parallel.

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Abstract

Water is a scarce resource in many places of the world, and the problem with access to clean water increases. There are several ways to mitigate the problem and produce clean water and one of them is atmospheric water generation (AWG). Although water is a scarce resource it occurs as a residual product from the drying process spray drying. The Uppsala based startup company Drupps has developed technology for water recovery using a liquid desiccant to absorb the residual hot fumes emitted into the atmosphere. The company has built a pilot plant in a test facility with the necessary components for the system.

The purpose of the thesis was to develop a product architecture to be retrofitted on existing productions that use spray dryers. The target customers was productions with spray dryers emitting approximately 250 000 cubic meters of moisture per hour. To develop a customer focused product, the product development method is based on the one presented in the book “Product design and development” by Karl T. Ulrich and Steven D. Eppinger from 2016. The thesis elicits customer needs, mainly through interviews, searching for solutions that solve similar problems, decision matrices.

The final concept design is an modular architecture, consisting of a load-carrying structure of a square cube frame with interface to enable more cubes to be connected. The majority of the components of the Drupps atmospheric water generation system fit inside the cubic frames, and by increasing and alternating the three different cubes, the system can fit a wide variety of volumetric flows as well as different potential customer segments.

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I would also like to express my deepest appreciation to Drupps for the opportunity to apply my research in a real-world context. This project provided a perfect transition from academia into the industry as an engineer. I am thankful for the chance to gain firsthand experience of the startup culture, and the unique challenges, passion, strong belief, and faith associated with such an environment. I am especially grateful to Fredrik Edström and Hanna Gustrin for their support and supervision of the thesis, and to Vera Franke for encouraging me to pursue this thesis at Drupps. My sincere thanks also go to Fredrik Edström and Mikael Nølborg for this opportunity, which not only made this thesis possible, but also sparked a passion for my future professional career. To all of you, along with the rest of the Drupps employees; Carl Enlund, Per Dahlbäck, Jonas Wamstad, Charlotte De Coster, Estefania Toledo and Robin Bergström, your approach, mindset and enthusiasm have left a life lasting impression. I feel truly fortunate to have been part of such an incurably optimistic, supportive, and inspiring atmosphere.

My favorite quote from Chalmers is “Because they didn’t ask”, said in a Swedish Gothenburg accent. I heard it in the context of portfolio management and developing products that did not meet the customer requirements. This quote now has a greater meaning to me, as it reflects the many potential opportunities lost simply by not asking. - I am glad I asked Drupps.

Lastly, if it had not been for CAS, I would probably not have made it as far as to the start of this thesis, thanks!

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1 Introduction

This master thesis in the master's program in product development at Chalmers University of technology. Following chapter will present a background to the thesis project, water scarcity, methods for Atmospheric Water Generation (AWG) to harvest water from air and the process of spray drying. Additionally, the thesis aim, research questions, delimitations, problem analysis and thesis outline will be presented.

1.1 Background

Water is essential for life. However, four billion people, almost two thirds of the world's population, experience severe water scarcity for at least one month each year. Over two billion people live in countries where water supply is inadequate and (Unicef, n.d.) claims that soon half of the world's population could be living in areas facing water scarcity. According to (UN-Water, 2021) many countries in the Northern Africa and Western Asia region withdraw all their renewable water resources and some even tenfold the capacity and therefore rely on non-renewable water resources that eventually will run dry.

Water stress is affecting Europe as well. According to the (European Environment Agency, n.d.) during an average year, 20% of the European territory and 30% of Europeans are affected by Droughts and water scarcity. UN-Water (2020) infers that the challenges of sustainably managing the already stressed water resources will be even worsened by the hydrological changes induced by climate change.

Although water is an increasingly scarce resource, the spray drying process has hot air with substantial moisture content as a residual product (Cherepanov, 2021), which is discharged into the atmosphere. Spray drying is a process of creating dry powder out of a liquid or slurry. The liquid is sprayed through a nozzle and the water in the atomized feed is rapidly evaporated by a mix with hot gas due to the large contact area of the small droplets. Spray drying is very quick compared to other methods such as sun drying, hot air drying, contact drying, infrared drying, freeze-drying. It turns a liquid into a dried powder in a single step with a fully automated continuous flow (McHugh, 2018) and is a suitable drying method for both thermal-sensitive foods and pharmaceuticals, but is also applied in ceramic, polymer, and chemical industries (Vehring et al., 2007). According to Schuck et al. (2008) it is the most widely used and cheapest technique (Gharsallaoui et al., 2007) to produce microencapsulated foods such as powdered milk and dairy products, eggs and whey protein. The process ensures microbiological stability, avoids the risk of chemical and biological degradations as well as reduces the storage and transport costs. For the pharmaceutical industry, it is used to manufacture complex particles with specific properties, like dispersibility and aerodynamic properties (Vehring et al., 2007) for pulmonary drug delivery. Despite the many advantages of spray-drying, Vehring et al., (2007) also asserts the process as an energy wasting operation due to the lack of utilization of all the heat going through the drying chamber.

Figure 1.1 Illustrates spray drying process as a black box diagram. The feed can be, for example, milk and milk powder as the power product.

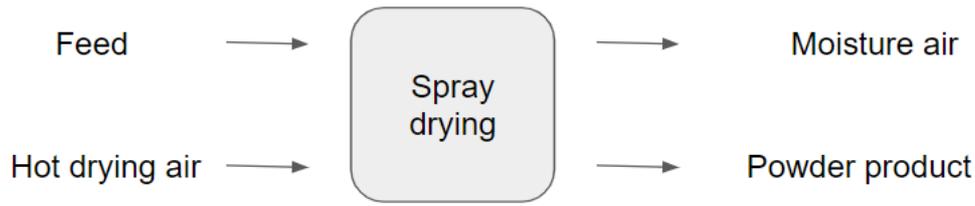


Figure 1.1. Black box flow from process scheme of single stage spray dryer (Patel et al., 2009)

1.2 Societal, ethical, and ecological aspects

The topics covered in this thesis are related to some of the Sustainable Development Goals United Nation have set related to clean water and sanitation, affordable and clean energy, industry innovation and infrastructure and responsible consumption and production.

Sustainable Development Goals (SDG) no. 6 set by the United Nations, states that safe and affordable drinking water should be provided to all (The global goals, n.d.). Sub-goals include “wastewater treatment and safe reuse” as well as “increase water-use efficiency and freshwater supplies”. This can be achieved by substantially increasing recycling and safe reuse. Regarding climate change, SDG 7, targets to improve energy efficiency and invest in renewable and clean energy (The global goals, n.d.).

Another SDG goal, target 9.4 (The global goals, n.d.), refers to retrofitting industries to make them sustainable, adopted with environmentally friendly technologies and increasing resource efficiency in industrial processes. SDG 12 was set with the ambition to ensure sustainable production patterns.

1.3 Company description

Drupps is a Swedish water innovation startup company based in Uppsala, specialized in evaporative water recovery. The company was founded in 2017 and currently has 10 employees. The company is registered as a water producing plant (Drupps, n.d.) and has developed a system for atmospheric water generation that uses a liquid desiccant to absorb the water from the humid air. Recently, they have found a business opportunity to recover water from the spray drying process, which emits hot humid air as residual product. The value proposition is to recover evaporative wastewater and its latent heat to the companies using spray dryers in their manufacturing of food and pharmaceuticals. This would be achieved by integrating the Drupps system with the spray drying process.

The central components in the Drupps system are the moisture absorber, which mixes the liquid desiccant with humid air in a cross flow and the evaporator which separates the water from the desiccant/ water solution through evaporation. Drupps have recently pivoted from the primary business idea of atmospheric water generation, this was due to the relatively large cost of certain few expensive components making the system infeasible in small scale. They have now established three new business areas, namely evaporative losses, Malt dryers, and spray dryers. When the project began no system had yet been sold. The company are highly motivated to sell the first large scale system, not sure witch segment will be first.

Figure 1.2 shows a flowchart of how a system from Drupps would interact with the spray dryer which is illustrated as the silver cylinder on the left side. Drupps has no physical installation or done testing with a system like this. The arrows going from blue to red, purple, and back to blue is the airflow. The ambient air, seen in the bottom right corner, entering the air to liquid heat exchangers is heated up before entering the heater with heats the air to the operational temperature for the spray dryer, which is illustrated by the silver cylinder. The hot humid air which exits the spray dryer is then cooled down by another heat exchanger which brings down the temperature on the exhaust moisture air before entering Drupps moisture absorber.

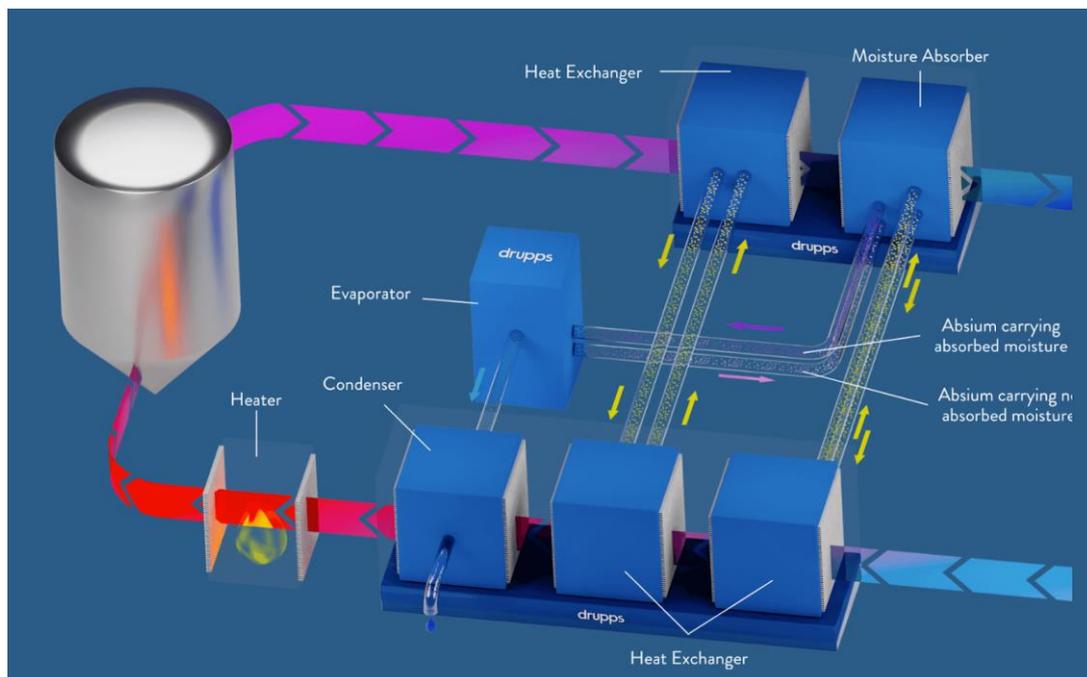


Figure 1.2: Flow chart of Drupps water generation system (Drupps, n.d.)

1.4 Problem description and aim.

The objective of this thesis is to investigate the integration of atmospheric water generation (AWG) technology into existing production processes that utilize spray dryers. Specifically, the study examines how the technology developed by Drupps, alongside its key components and stakeholder interests, could be applied to enhance efficiency within such systems. Through this integration, the project aims to address both technological requirements and market demands for implementing AWG within various spray drying applications.

Since spray dryers are found across a broad spectrum of industries and vary significantly in size and specifications, an optimized AWG integration should be adaptable to different spray dryer configurations. This includes variations in temperature, humidity, volumetric flow rates, and the presence of contaminants and residual particles from the drying process. The proposed solution should cater to a diverse customer base by anticipating emerging needs, offering cost-effective designs, and minimizing the costs associated with development, redesign, and implementation for future clients.

The integration of AWG technology presents several potential benefits for production facilities using spray dryers, including water conservation, reduced energy consumption, lower costs,

and decreased CO₂ emissions. Notably, the greater the volume of residual hot, moist air from the spray dryers, the higher the potential gains in water recycling.

In summary, this thesis aims to explore the integration of Drupps' AWG technology, designed to capture water from humid air, into industrial processes using spray dryers, which emit hot, humid air as a byproduct. The focus is on applications with large airflows, specifically at rates around 250,000 m³/h.

1.5 Research questions

The aim can be achieved by answering the following research questions:

- RQ1 - What are the needs and constraints for companies using the spray drying in their manufacturing process?
- RQ2 - What product architecture can satisfy the needs and constraints of the currently used AWG technology?
- RQ3 – How can a concept be designed to meet stakeholder needs and requirements for integrating current AWG technology into existing industrial processes that use spray dryers?

1.6 Limitations

The current system is rather complex and has been developed over a long time by highly experienced engineers in their field. Therefore, no changes will be made to the current components in the Drupps system. Due to the global market for the product, neither regional or country-specific laws and regulations regarding product architecture nor safety regulations will be taken into consideration. This thesis will only handle the mechanical aspect of the product architecture regarding integration.

1.7 Outline of the report

Introduction - Elaborates on the thesis' background along with its aim, research questions, limitations and background about Drupps, the company providing a case for this research.

Methodology - Presents the methodology used in the thesis and the major steps of identifying customer needs and systematic concept design.

Theory – Presents theory on product architecture and modularization.

Method – walkthrough of how each step in the thesis was carried out.

Result – The results of benchmarking, product statement, customer needs, product specifications, concept generation, product architecture and clustering as well as the final design.

Future steps – Highlights the key areas for continuing the development.

Discussion – Discussing the results and answers to the research questions, highlighting challenges encountered during the thesis work, and reflections on the development process used in this thesis.

Conclusion – Summarizing the results and final comments

2 Methodology

The product development process used in this thesis will be based on the one described in the book “Product design and development” written by (Ulrich & Eppinger, 2016). It provides methods for identifying customer needs, product specifications, concept generation, concept selection and product architecture, as can be seen in figure 2.1. This process was selected for its effectiveness in systematically exploring the entire development process, from establishing a mission statement and identifying customer needs to applying concept selection methods. Another factor in this choice is that it is taught at Chalmers University of Technology, making it both a familiar and academically rigorous approach.

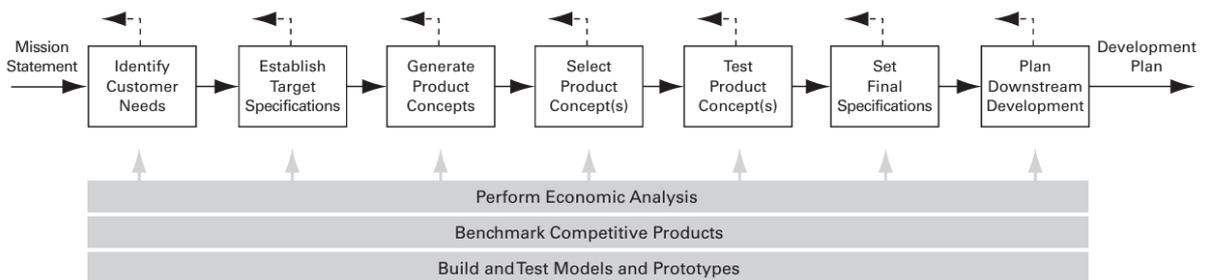


Figure 2.1: Product development process from the book “Product design and development” (Ulrich & Eppinger, 2016)

2.1 Product planning

Before the actual development, which starts with identifying customer needs, Ulrich & Eppinger (2016) suggests researching the potential markets segments, identifying opportunities and benchmark competitors for new products. Then to evaluate, prioritize, plan and allocate resources to the most promising projects with regards to a carefully balanced product portfolio. By then, the development team can use the above-mentioned as input to form a mission statement for the upcoming development. The mission statement specifies the target market, business goals, key assumptions, constraints, and the product’s stakeholder.

2.2 Identifying customer needs.

Customer needs in the development process are critical for all types of development, both new revolutionary products as well as incremental changes to existing ones and developing products focused on the customer needs is of utmost importance. Accurate understanding of user needs has been shown to be key to successful innovation (Rothwell, et al., 1974). Successful innovators were found to have a good understanding of user needs. The economic success of most firms depends on the ability to identify these needs and quickly develop customer focused products at low cost that meet these needs. A solid record and a fact base with needs from all stakeholders and aspects of the product therefore is of utmost importance for a successful product. The needs should be identified without knowing how or if they will be implemented in a particular product or concept, they should also express what the product should do, not how.

Ullrich & Eppinger (2016) describes the process of identifying Customer Needs by the following steps and order:

- Gather raw data from customers.
- Interpret the raw data in terms of customer needs.
- Organize the needs into a hierarchy of primary, secondary, and (if necessary) tertiary needs.
- Establish the relative importance of the needs.

2.2.1 Gather raw data

Gathering data from all important stakeholders involved in the product, as well as all situations, the end customer or user interacts with the product helps elicit an honest expression of all possible needs. Although, some of the needs are harder to find than others. Explicit needs are the ones customers can tell during an interview, but latent needs are the needs customers do not explicitly articulate and are hard to recognize, finding these will therefore give the ability to create products that positively surprise and delight customers. Latent needs can best be found by observations and reading between the lines in customer interviews.

Using multiple data gathering techniques helps triangulate the customer's needs. Suggested methods are interviews, observations, and surveys. Unfulfilled needs could also be found in product reviews. Advice for conducting interviews is to prepare open ended questions and to "go with the flow" during the interview. This means that if the customer is providing useful information, one should not worry about deviating from the prepared interview questions. A customer that mentions something surprising should be acknowledged and pursued with follow-up questions, because unexpected lines of questioning may reveal the latent need. To facilitate finding needs independent of a specific product, preconceived hypotheses about the product technology should be avoided.

Observing users handling an existing product or performing a task for which a new product is intended can reveal important details about needs. Observations are also a good way to enhance the chances of finding latent needs since latent needs are not explicitly articulated.

No matter if the customers can fully articulate their true needs or not, interacting with customers in the target market helps build a personal understanding of the user's needs and environment. That knowledge is always useful, regardless of whether all the needs for the new product are identified or not. Those who directly control the details of the product should therefore interact with customers and experience the user environment.

Documenting interactions with customers audio recordings and videotaping is suggested because it minimizes the risk of only remembering the most surprising or last part of the interview, which often is the case. Although recording has the disadvantage of being intimidating to some interviewees.

2.2.2 Interpreting the needs

To know what the product should accomplish, the raw customer data is interpreted and formulated as customer statements. These should express needs in terms of what the product

should do, not how. The level of detail should be expressed similar to the raw data to avoid loss of information. Although not strict guidelines, positive phrasing and expressing the need as an attribute of the product should be strived for, due to easier translate the needs into a product specification. Words as “must” and “should” imply a level of importance for the need and should therefore be avoided, the importance of needs is determined later.

2.2.3 Organize the needs into a hierarchy

To have an overview and facilitate working with many needs, a hierarchy of primary and secondary needs are formed. The primary needs are the most general needs and secondary more detailed. The redundant statements should first be eliminated, and the unique statements are clustered with others that express similar needs, and not by any technical aspect. It is suggested to clustering three to seven secondary needs expressing similar needs from a customer point of view. If there are more than twenty groups, a third level of needs is suggested.

2.2.4 Establish the relative importance of the needs

Each subset of needs can then be asserted as a number to display the importance of those needs. This can be done either by relying on teams’ experience with customers, or letting customer rank the importance.

2.2.5 Product specifications

When the customer needs are found and sorted, the next step is to establish specifications with measurable details, number, range, or inequality, with units (e.g., seconds, kilograms, joules), linked to the specific needs. The specifications do not tell how the product should perform or satisfy the customer but a threshold for what the product should achieve to satisfy the customer’s needs. Ulrich & Eppinger (2016) suggests starting by preparing the list of metrics and then from competitive benchmarking set ideal and acceptable target values. Sometimes values for needs such as “easy to install”, that can be measured in both time and safety can be contradictory because a fast installation may affect the safety.

For technology-intensive products specifications are established at least twice, first after identifying the customer needs, and later when the final concept is decided, a refinement is made.

The metrics should be practical and realistic. Unquantifiable metrics, such as esthetics, can be noted by “subjective”, but should nevertheless somehow be evaluated and confirmed. This can be done through asking relevant stakeholders for their opinion. The values can be set as a minimum value, maximum value, a range, a specific value, or a set of discrete values. The goal is to match the target values, but due to the reality of making tradeoffs, a product can be successful although not all target values are attained.

2.3 Systematic concept design

Systematic concept design is a methodology to provide a structured approach to developing innovative solutions. By breaking down complex problems into manageable components, it ensures that each aspect of the design process is analyzed and aligned with project aim and objectives. This method supports the generation, evaluation, and refinement of concepts, which

helps decision-making and increases the likelihood of achieving a successful product development.

2.3.1 Problem decomposition and idea generation

Problem decomposition

Problems that are technically intense and complex are easier to handle if broken down into simpler subproblems, this is called problem decomposition and can be performed in various ways. Ulrich & Eppinger (2016) demonstrate functional decomposition, where a single black box of the overall problem is divided into subfunctions that more specifically describe what the elements of the product should accomplish and are simple enough to work with. Between 3 and 10 subfunctions in the diagram are suggested. Although, in some systems where material, energy, and signal flows are difficult to identify, just listing the subfunctions without connections between them can be sufficient.

Search Externally

Searching external sources for information and inspiration for potential solutions to the subproblems is an important method of gathering solution concepts. Implementing an existing solution is often quicker and less expensive than developing a new one and allows more time and creative energy for the more critical subproblems without existing satisfactory solutions. Conventional solutions to one subproblem can be combined with a novel solution to another subproblem to yield a superior overall design. Therefore, technologies from other industries and areas with related subfunctions should also be included in the external search. The suggested external sources to investigate include lead users, expert consultation, patent searches, literature searches, and competitive benchmarking.

Interview Lead Users

In high technology industries, proposing that "lead users" with real-life experience of the product or process concepts are essential to gain accurate marketing research (von Hippel, 1986) and are able to provide accurate data on needs related to future conditions and therefore provide great benefit for product innovation.

Consult Experts

Experts with knowledge of one or more of the subproblems can provide solution concepts directly as well as give advice on related areas to which interesting and specific solutions might be found.

Search for Patents, Published Literature, and the internet.

Patents containing technical information, detailed drawings and explanations which can be of use or inspiration. Although some patents are protected, they are useful to avoid patent infringement.

Benchmark Related Products

Benchmarking in the context means searching for existing products with similar functionality or products with similar subproblem. The products can also be from completely different markets, but with related functionality.

Search Internally

This is often called brainstorming, and the goal is to use personal and team knowledge as well as creativity to generate solutions to subproblems. Guidelines include making sketches, generate many ideas and not criticize to ideas that are Infeasible, extreme, or unrealistic, as they can stimulate new ideas.

2.3.2 Concept generation

The concept combination table provides a systematic way to combine solution to each identified problem. Using a matrix with subproblems on one axis and sub solutions to that problem on the other axis, solutions to the problem can be found by combination of one sub solution to each subproblem. It is suggested to make the process easier and more practical by not exceeding three or four sub-solutions to each problem as well as to eliminate infeasible sub solutions before combining. Also, to concentrate on combinations that can be combined with regard to, for example, a source of energy.

2.3.3 Concept evaluation

Concept selection is used to narrow down the number of generated concept alternatives. Although it is a convergent process, it may be beneficial to iterate the process. A dominant concept does not have to be produced immediately from the set of initial concepts, the concepts may subsequently be combined and improved to temporarily enlarge the set of concepts under consideration. The structured process is meant to help maintain objectivity and guide through critical, difficult, and sometimes emotional processes. Because the concepts are explicitly evaluated against customer-oriented criteria, the remaining concepts also are likely to be customer-focused.

Ulrich & Eppinger (2016) present a two-stage concept selection methodology, although they claim that the first stage may suffice for simple design decisions. The first stage is called concept screening, and the second stage is called concept scoring.

Concept Screening

When evaluating the concepts, they should be presented at the same level of detail for meaningful comparison and unbiased selection and are best portrayed by both a written description and a graphical representation to communicate the key features of the concept.

The concept screening Matrix

The concept screening matrix is prepared by listing the selection criteria in the left-hand columns and the concepts which are to be evaluated on the top row. The criteria are chosen based on the customer needs as well as the company's needs, such as manufacturing costs or risk regarding the product. The criteria may be at a high level of abstraction and typically include 5 to 10 dimensions and be chosen to differentiate among the concepts. Due to the equal weighting of the criterion, caution should be taken to not list many relatively unimportant criteria, as the differences among the concepts relative to the more important criteria will not be clearly reflected in the outcome. Next, a reference, or benchmark concept that the other concepts are rated against is then decided. The reference can be a straightforward concept, a concept to represent the best features of different products, an industry standard or a commercially available best-in-class product or an earlier generation of the product.

Rating the Concepts

Relative to the reference concept, score of “worse than” (-), “same as” (0) or “better than” (+), is placed in each cell of the matrix to represent how each concept rates for that criterion in comparison to the reference concept. The number of “better than,” “same as,” and “worse than” scores are then summed and displayed in the matrix. The concepts are then ranked by the result of adding up the sums. At this stage, a few criteria that seem to differentiate the concepts can be identified.

Improve by combining the Concepts.

After ranking the concepts, the results should be reviewed to make sense and then ways to combine and improve certain concepts should be considered. Suggestions from Ulrich & Eppinger (2016) is to investigate if there a good concept is degraded by one bad feature or if a minor modification could improve the overall concept and yet preserve a distinction from the other concepts. Also, to combine two concepts and preserve the “better than” qualities while removing the “worse than” qualities. The newly combined and improved concepts are then added, rated, and ranked along with the original concepts in the matrix.

Concepts for further development

If the results from the matrix are satisfactory and each concept qualities understandable, the most promising concepts are to be selected for further refinement and analysis. The number of concepts selected for further review will be limited by team resources (personnel, money, and time).

Concept Scoring

If multiple concepts have been refined in more detail after the concept screening, a more nuanced detail to the selection criteria. The level of criteria detailed will depend upon the needs, and it may not be necessary to expand the criteria at all, but the secondary and tertiary needs are good candidates for more detailed selection criteria. To add importance weights to the criteria, several different ways can be used to weight the criteria, for example assigning an importance value from 1 to 5 or percentage which reflect the importance. To avoid scale compression, one main reference concept is selected, but separate reference point from other concepts can be chosen to represent a better reference for that specific criterion. As the previously mentioned method, the concept is ranked, and the weighted score is summed. Iterations and combinations of concepts, before moving on with further development, are as useful for this method as the previously mentioned method.

2.4 Prototyping and testing

Within a product development project, prototypes are used for learning, communication, integration, and to demonstrate. They can also reduce the risk of costly iterations. Depending on available resources and purpose, different types of prototypes are used. Figure 2.2 shows recommendations of how to approach the use of prototypes with regards to number and type, depending on level of risk and cost. Physical prototypes are tangible objects created to represent the product, while analytical prototypes represent the product in an intangible, mathematical or with visual means. Analytical, intangible, prototypes are often more flexible than physical, although physical ones are required to reveal unanticipated phenomena (Ulrich & Eppinger, 2016).

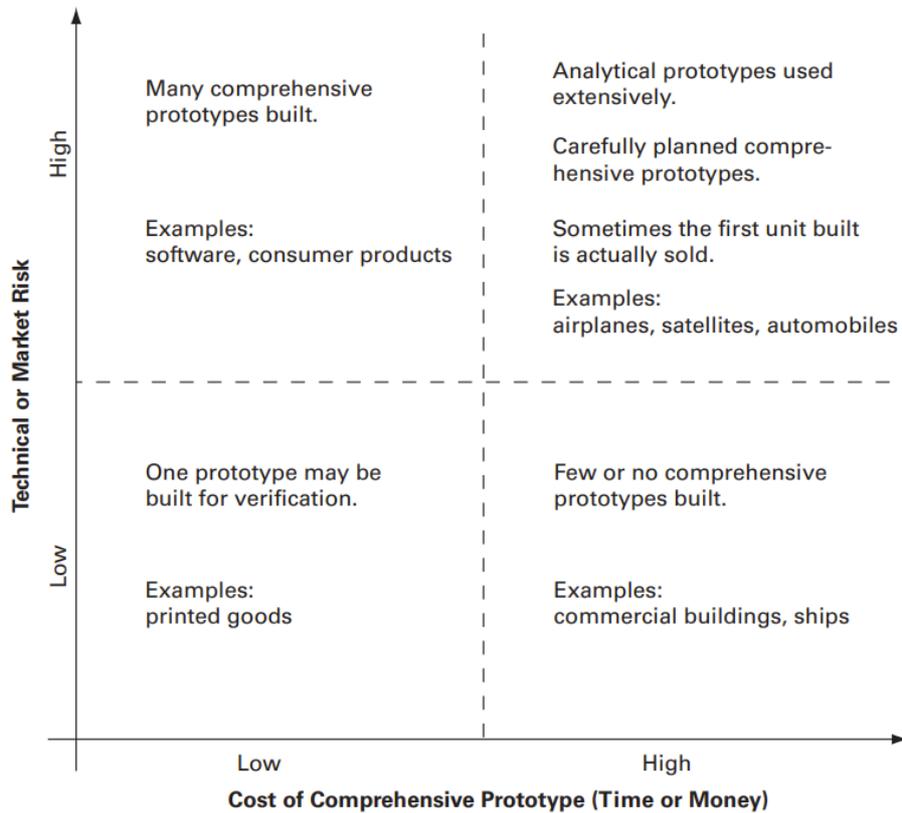


Figure 2.2. Guiding chart of how to use prototypes in development projects. (Ulrich & Eppinger, 2016).

3D CAD modeling helps visualize the three-dimensional form of the design evaluation of product appearance. Advanced and comprehensive 3D CAD models with integrated assembly can detect geometric interference among parts and may eliminate the need for a full-scale prototype, they are also the foundation for many types of computer-based analyses such as finite element simulations.

Figure 2.3 showing what type of prototype is suitable for the specific purpose. How physical and what level of attributes the implemented in the prototype.

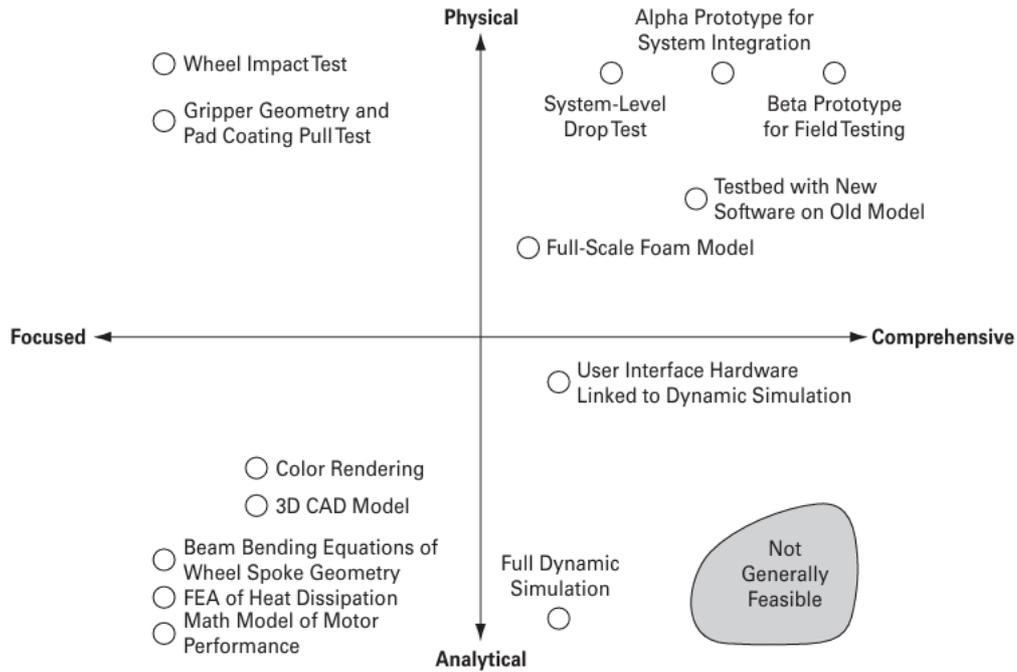


Figure 2.3 Guide on what prototype to use (Ulrich & Eppinger, 2016)

Before starting the prototyping, it is important to define the purpose, establish the level of approximation of the prototype, form an experimental plan and schedule the plan. The *purpose* may be to learn more, communicate, test integration and demonstrate. Learning about the concept can include investigating if the concept will work and if it meets the customer's needs. Communication may enrich the understanding with customers, partners, investors, vendors, team members and top management. Integration means to ensure that components and subsystems of the product work together as expected. Demonstration is used to ensure that the product has achieved a desired level of functionality, especially in later stages of the development. To *establish the level of approximation*, a decision has to be taken about whether a physical prototype or an analytical would best meet its needs. In most cases, the best prototype is the simplest prototype that will serve the purposes established. *Planning* includes the identification of the variables of the experiment, the test protocol, an indication of what measurements will be performed, and a plan for analyzing the resulting data. Lastly, *scheduling* implies when to do what.

Next after prototyping is testing. The goal of testing is to gather insights and understand the potential market response to your product concept and collect information from potential customers on how to improve a concept for further development. Concept testing is an experimental activity, and knowing the purpose of the experiment is essential to designing an effective experimental method. The information gathering methods are similar to the ones for gathering customer needs, although some methods are more suitable when showing or testing a physical prototype, since it requires interacting with the customer physically.

3 Theory

In this chapter theory regarding product architecture and modularization is covered.

3.1 Product architecture

Product architecture includes *functional elements*, which are operations and transformations that contribute to the overall performance and *physical elements* which are components, parts, and subassemblies that implement a product's functions. Furthermore, the physical elements are typically organized into several major physical building blocks, called chunks (Ulrich & Eppinger, 2016). Each chunk contains components that implement the functions of the product. The architecture is the scheme by which the functional elements are arranged into physical chunks and how they interact.

Maybe the most important characteristic of a product's architecture is its modularity (Ulrich & Eppinger, 2016). A modular architecture has chunks that include one or a few functional elements in their entirety, the interactions in a modular architecture between chunks are well defined and fundamental to the primary functions of the product.

3.1.1. Modular and integral architectures

There are a spectrum of modularity as well as different types of morality. The most modular architecture has each functional element implemented in one chunk with few well-defined interactions between the chunks. Such a modular architecture allows a chunk to be redesigned independently without requiring changes to other chunks for the product to function correctly. On the other side of the spectrum of modular architecture is the integral architecture. In an integral architecture, the implementation of functional elements may be distributed across multiple chunks. Boundaries between the chunks may be difficult to identify and many functional elements may be combined into a few physical components to optimize certain dimensions or performance. However, modifications to one component or feature may require extensive redesign of the product. An example of this is an integrated gear and brake handle for road bikes. Modular architecture therefore often allows components to be shared, which integral architectures does not.

3.1.2 When to choose a modular architecture.

Modular systems with distinct interfaces must pay a price that integrated systems do not. The benefits of the modularity may not be worth this cost for a system that develops slowly and is used in environments that never change or change slowly may not require much modularity. Although, in markets where change is present, modularity is most often worth the cost, the challenge is normally not whether to develop a modular product but *how* and *what* interfaces will gain the system the most (Langlois, 2002). If it is possible to predict which areas in a project are likely to be changed by new information gained, and which other areas are likely to be affected by that new information. It is beneficial to partition that area to minimize the cross-boundary problem-solving interdependence (von Hippel, 1990).

The value of long-lived products with long service life increases if they can easily be upgraded. Airbus A380 was designed for much potential adaptability, with a reconfigurable cabin layout and infrastructure to support not yet available electrical systems for comfort and entertainment. Relatively short-lived products that may not be upgraded by the user, such as smartphones, can benefit developers and manufacturers if designed for adaptability. Even if it is not visible to the product's users, the modular design facilitates manufacturing, outsourcing, redesigning, and upgrading internally at the company, if split into somewhat independent modules. (Engel, Browning, & Reich, 2017)

Product architecture and modularity also affect innovation. Companies with organizational structure similar to the structure of their products has been efficient in stable environments (Fixson, 2007), but may be blind to competitive architectural innovations, that is changes in the architecture of the product without changing its components (Henderson & Clark, 1990). Increasing modularity i.e. interdependent components may also decrease the likelihood of breakthrough innovation (Sorenson & Flemming, 2001). However, modularity could increase innovation due to the possibility of developing and innovating multiple chunks in parallel. (Fixson, 2007)

3.1.3 When to define the product architecture.

The architecture begins to form informally during the concept development when drawing function diagram, sketches and making prototypes. Product architecture has a great impact on a company's ability to produce a high product variety and becomes a central part of the product concept. Although, when the product is new of its kind, the product architecture is often the initial focus in the system-level design phase, which includes decomposition of the product into subsystems and components as well as preliminary design of key components. If the elements are not decided where to be assigned to modular chunks, the potential for modular innovation will be limited. On the contrary, freezing the modular design too early may cause an inferior modularization. In some cases, the benefits of modular innovation and recombination outweigh mistakes in modularization (Langlois, 2002).

The level of modularity on the architecture are closely linked to important areas affecting both the product and the company's overall strategy, namely product change, product variety, component standardization, product performance, manufacturability, and product development management and marketing strategy.

3.1.4 Effects of the architecture

Product Change

The architecture defines how the product can be changed; modular chunks allow changes to be made to a few isolated functional elements of the product without necessarily affecting the design of other chunks. Changing an integral chunk may influence many functional elements and require changes to several related chunks. Motives for product change are upgrades, additions, adaptation to long lived products, replacement of wear out components.

Product Variety

Variety refers to the range of product models regarding market demand. Product variety should be considered both to the current product line, and variety across future generations of the product to decrease the effect of variety increasing the cost of a product (Ishii & Martin, 2002). Modular product architectures can be varied without adding immense change in manufacturing system. Different product models but can be achieved at relatively low cost by assembling the

variants from different combinations of standard chunks. Customized products with high variation benefits both customers and producers. The product portfolio serves the customer needs better and improving resource utilization for producers and increases market share by expanding the product range (Liu & Hsiao, 2006).

Component Standardization

Standardization is the use of the same chunks or components in multiple products in the company's product portfolio. If a chunk possesses functional elements used in several different products, the chunk can be standardized to fit those as well. By manufacturing the chunk in higher volumes reduces the costs and increases quality.

Supply chain and postponement.

Postponement, or delayed differentiation, means delaying the differentiation of a product until late in the supply chain, and may offer substantial reductions in the costs of operating the supply chain, due to reductions in inventory requirements. The two necessary design principles for postponement are that the differentiating elements of the product must be concentrated in one or a few chunks and that the product is designed so the differentiating chunk(s) can be assembled near the end of the supply chain.

Figure 3.1. shows how product differentiation can be postponed downstream in the supply chain and the final product can be formed late by alternating a few specific components.

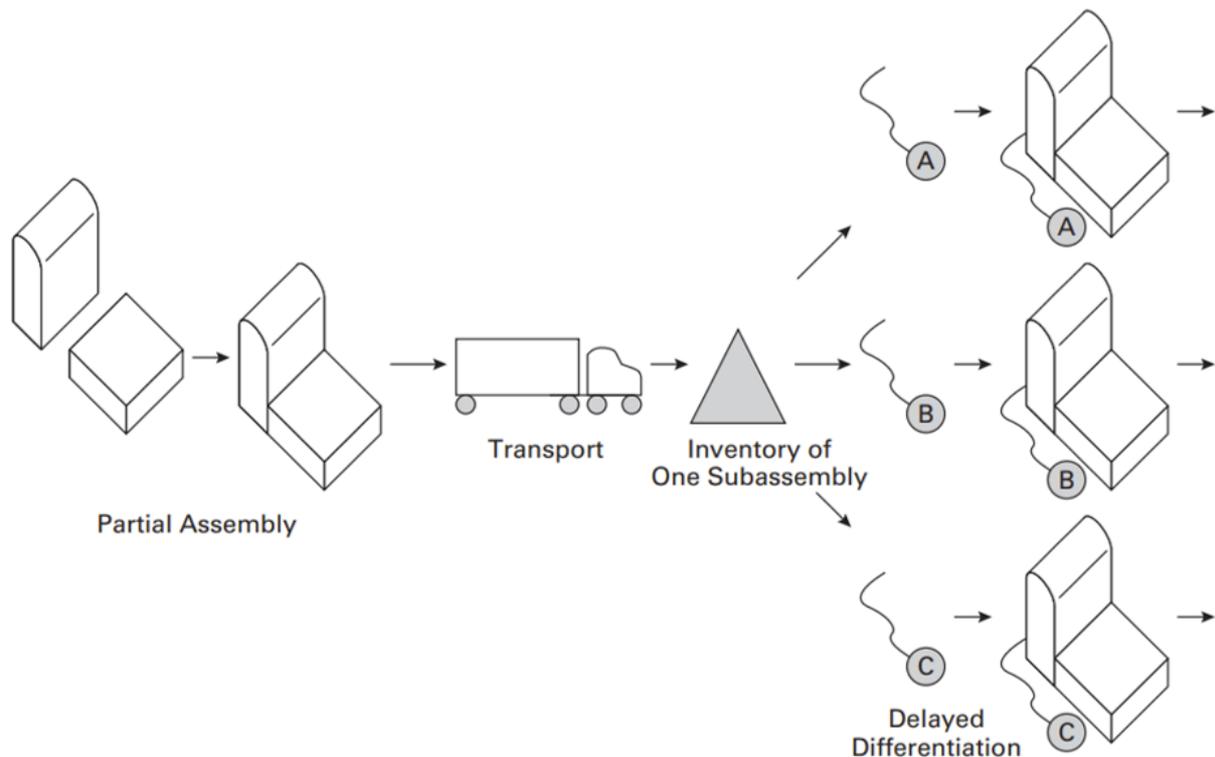


Figure 3.1 How postponement works in the supply chain (Ulrich & Eppinger, 2016).

3.1.5 Establishing the architecture

The first step to create a schematic of the Product, doing this during the concept development phase, the elements in the schematic can be physical concepts, critical components, and other

described functionally. A good rule of thumb is to aim for fewer than 30 elements in the schematic, for the purpose of establishing the product architecture.

Next step is to cluster the elements of the schematic and assign each of the elements of the schematic to a chunk. To manage the complexity of the alternatives each element of the schematic can initially be assigned its own chunk, and successively clustering elements together when found advantageous. To determine the advantages of clustering, Ulrich and Eppinger (2016) suggest considering the following factors along with previously mentioned strategies.

Geometric integration and precision: Assigning elements to the same chunk allows a single individual or group to control the physical relationships among the elements. Elements requiring precise location or close geometric integration can often be best designed if they are part of the same chunk.

Function sharing: When a single physical component can implement several functional elements of the product, these functional elements are best clustered together.

Capabilities of vendors: A trusted vendor may have specific capabilities related to a project, and to best take advantage of such capabilities a team may choose to cluster those elements about which the vendor has expertise into one chunk.

Similarity of design or production technology: When two or more functional elements are likely to be implemented using the same design and/or production technology, then incorporating these elements into the same chunk may allow for more economical design and/or production. A common strategy, for example, is to combine all functions that are likely to involve electronics in the same chunk. This allows the possibility of implementing all of these functions with a single circuit board.

Localization of change: When a team anticipates a great deal of change in some element, it makes sense to isolate that element into its own modular chunk, so that required changes to the element can be carried out without disrupting any of the other chunks.

Accommodating variety: Elements should be clustered together to enable the firm to vary the product in ways that will have value for customers. The printer was to be sold around the world in regions with different electrical power standards. As a result, the team created a separate chunk for the element associated with supplying DC power.

Enabling standardization: If a set of elements will be useful in other products, they should be clustered together into a single chunk. This allows the physical elements of the chunk to be produced in higher quantities.

Portability of the interfaces: Some interactions are easily transmitted over large distances. For example, electrical signals are much more portable than mechanical forces and motions. As a result, elements with electronic interactions can be easily separated from one another. This is also true, but to a lesser extent, for fluid connections.

The last step is to create a rough geometric layout. It can be created in two or three dimensions, using drawings, computer models, or physical models now the physical interactions are identified and formed. At this stage, the definition of secondary systems, which are functions and physical elements not shown in the scheme, will start to be conceived. The secondary systems include safety systems, power systems, status monitors, and structural supports. Some of these systems will span several chunks but usually involve flexible connections such as wiring and tubing and can therefore be considered after the main architectural is decided.

Figure 3.2 shows elements in a schematic of a printer, the squares are forming chunks, the connections between the elements are signals or flows.

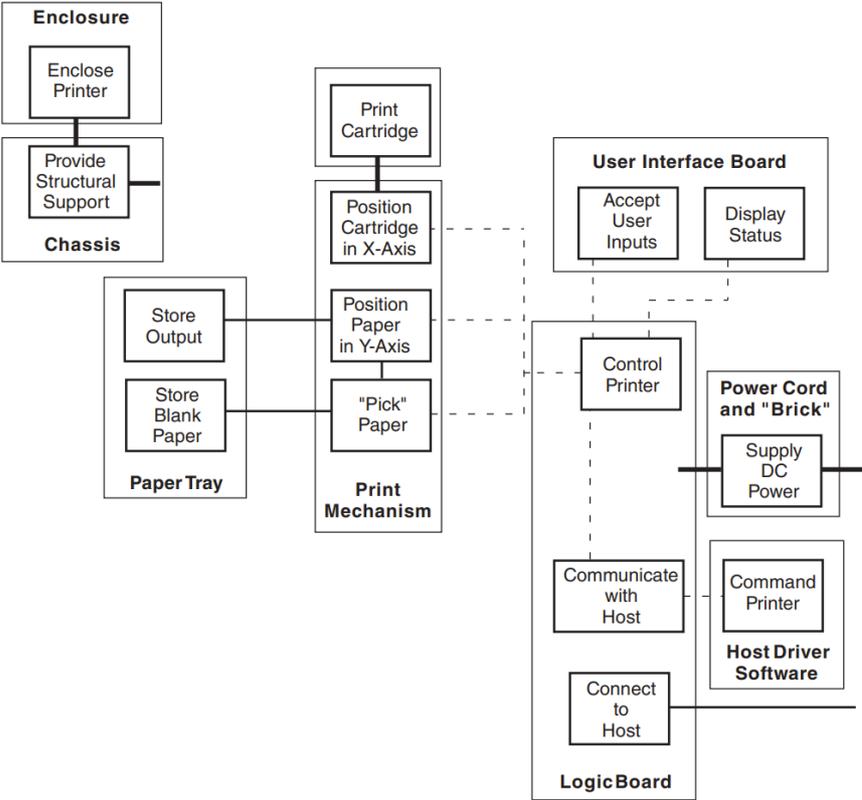


Figure 3.2 Elements clustered in chunks when found advantageous. (Ulrich & Eppinger, 2016).

3.1.6. Modularization interfaces

Three types of modular architectures will be used: slot, bus, and sectional, what differs the types is how the interactions between chunks are organized (Ulrich & Eppinger, 2016).

Slot-modular architecture holds different interfaces between chunks depending on function so that the various chunks in the product cannot be interchanged. For example, a radio has a specific interface to the instrument panel. This is the most common of the modular architecture because for most products each chunk requires a different interface to accommodate unique interactions between that chunk and the rest of the product.

Bus-modular architecture has common bus to which chunks connect through the same type of interface. One example is modular shelving systems with rails and expansion cards for a personal computer.

Sectional-modular architecture comprises of chunks with identical interfaces, but nobody to attach the chunks to. The assembly is aggregated by connecting the chunks to each other. Sectional sofas and piping systems adhere to this type of modular architecture.

Both bus-modular and sectional-modular architectures are useful for situations where the overall product must vary widely in configuration. Although that requires the chunks to interact with the rest of the chunks of product using the same type of power, structural attachment, fluid connection, or exchanges of signals.

Figure 3.3. Illustrating different types of modular architectures. The connections indicate if the pieces can be changed and replaced by another chunk.

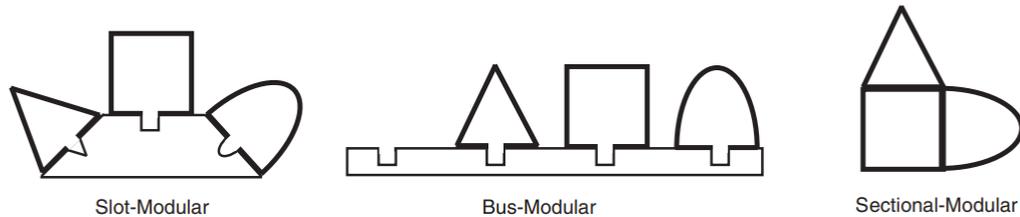


Figure 3.3. Three types of modular architectures. (Ulrich & Eppinger, 2016).

3.4 Modular constructions

Modularization can be applied in constructions of family houses, schools, high-rise and apartment buildings, and can transform traditional onsite projects to offsite production.

Prefabricated modular constructions projects have a mixed track record of cost savings, they can potentially save up to 20 percent, but risk of up to 10 percent increases in cost, depending on logistics and materials costs in relation to labor savings as well as if the design is optimized for the scale and repeatability. Projects with labor-intensive activities and high repeatability will have the highest savings. Although, they have consistently been completed 20 to 50 percent faster than traditional onsite builds (Bertram, et al., 2019).

Contrary to individual construction projects, modular constructions focus on design, production, technology, logistics, and assembly. Because the modular construction requires standardized components manufactured offsite and assembling them onsite. A project's specific requirements will determine the choice of modular system. 3D volumetric design has potential for maximum efficiency and time savings, but disadvantage in transportation costs and size limitations. They are most suitable for highly repetitive projects, not meaning all products look the same, but with variations of standardized modules assembled to customize the final construction. 2D panelized design, like flat-pack home furniture is more complex to assembly and requires more touch up. The benefit is transportation. Panel are therefore suggested for optimized logistics, differentiation, and design flexibility. Volumetric design is preferred for cost reduction, standardization, and repeatability.

The benefits are that lean offsite manufacturing process is faster than building process onsite due to the controlled factory environment, and repetitive activities, which can be automated. The onsite construction work is simplified, and results are assembling modules, which is cheaper and faster. The quality control is simpler in the factory environment compared to the construction site, which reduces rework.

4 Method

The method used for the thesis is based on the steps and tools described in the product development process chapter. It is a well reputable method thought of at universities and accepted among the academic community.

4.1 Product planning

Drupps have identified potential markets and business opportunities. However, to support concept development in the thesis, a clear mission statement provides direction for the development process and benchmarking is essential for creating a competitive product. Consequently, a mission statement was formulated for this thesis, and benchmarking was conducted to guide product development.

4.2 Benchmarking

The benchmarking process involved identifying competitors offering products related to Drupps' focus areas, specifically in primary water recovery and secondary thermal energy recovery. Given the numerous variables associated with spray dryer outlet air—such as flow rate, humidity, temperature, and chemical composition—a detailed comparison fell outside the scope of this thesis. Instead, a high-level overview of competitors was conducted and presented in a comparative diagram.

4.3 Mission statement

A mission statement was created for the upcoming development. The mission statement specifies the target market, business goals, key assumptions, constraints, and the product's stakeholder. The internal stakeholders' section was not in the theory but added to clarify and differentiate some possible internal interests which might be relevant to investigate for the product architecture. To elicit needs from each area, employees responsible for these areas were interviewed.

4.4 Identifying customer needs

This chapter of the method explained how customer needs were elicited through interviews and observations, interpreted, organized, and prioritized to form a product specification and know what the product should do.

4.4.1 Gather raw data

In accordance with the development process described by Ulrich and Eppinger (2016) raw data from the stakeholder and lead users were gathered to have a solid base for a customer focused product. To better triangulate the customer needs, lead users from manufacturers of spray dryers, project leaders in the energy sector, retailers for heat exchangers and technicians were contacted and interviewed. The manufacturer of spray dryers has the accumulated knowledge of many different spray drying users in several sectors, with different need and can therefore give a holistic view as well as possesses knowledge of the common needs along with what differentiates between the manufactured products. The consultants in the energy sector have long experience of different projects and therefore have encountered many different and extreme situations. The experts in heat exchangers have also encountered many different customers with a wide variety of needs. The technicians that were contacted have excellent experience of practical matters in technical products and machines. They all had experience of heat pumps, ventilation, coolers, piping and similar fields.

To elicit as much information as possible from each stakeholder, semi-structured interviews were conducted. Before every interview, relevant questions were prepared considering the interviewee's area of responsibility and expertise. The interviews can be found in Appendix A. The interviews lasted from about 35 min to 60 min, with the longest about 80 min.

Some of the interviewees were asked to be recorded to better focus on the interview and asking follow-up questions, but as mentioned in the theory, in order not to restrict the answers, during most interviews no recording was made and only notes were taken during the interview. This has also to do with the fact that the manufacturers were conservative about what information they were willing to share. When interviewing the manufacturers of spray dryers and companies using spray dryers video calls were made to better interpret gestures and facial expressions.

Observations were also made at Drupps test facility. The observed activities were among other things, loading equipment into containers which were commonly used, daily operation of the system, calibrations and testing of new and existing sensors, programming of safety features, connecting physical parts in the system and making measurements of airflow distribution over the pad. Some observations were documented by taking photographs and later analyzed and added to the needs list. The containers used were mostly standard 20 feet shipping containers, measuring 6,06 meters in length, 2,44 meters in width, and 2.59 meters in height for standard container or 2,89 meters in height for High cube containers.

When the answers from stakeholders with similar responsibilities and areas of expertise started to repeat and not provide new needs, the needs were assumed to have converged and no new stakeholders from that area were contacted.

4.4.2 Interpreted the customer needs

After the interviews, the recorded interviews were transcribed and analyzed along with the notes from the interview that were not recorded. From each interview, customer needs statements were formulated in terms of what the product should do, not how. The level of detail the needs was described were reflected on the statement, which was formulated in positive phrasing and without any implication of how important the need was.

4.4.3 Organize the needs into a hierarchy

To get a better overview, all needs were clustered by how similar the needs were forming a customer perspective and not by any technical attribute. The redundant statements were removed, and the remaining statements were clustered and sorted into primary and secondary needs.

4.4.5 Relative importance of the needs and product specifications

Because the customers were hard to reach and did not respond to the needs were, ranked based on the impression and statements from the interviews with all stakeholders as well as communication with Drupps employees.

4.5 Systematic concept design

This chapter will present methods used in the concept design phase of the project.

4.5.1 Problem decomposition

To systematically analyze the problem, the functional decomposition approach was employed, leading to the creation of a function diagram that breaks down the primary problem into smaller, manageable subproblems.

4.5.2 Idea generation

In Drupps pilotplant there is no installed equipment for transferring heat, but an integration of the Drupps system onto a spray dryer will require it. To address the heat transfer challenge, various system configurations were explored, including both air-to-air and air-to-liquid systems. These options were considered based on the potential need to transfer the heated media at the customer site, which would depend on factors such as the production layout and the distance between the air inlet and outlet of the spray dryer. Therefore, external sources for the heat transfer function were investigated to widen the solution space, the same goes for the modularity idea inspiration. In the search for modular solutions suitable for this project different industries were investigated, medical, production, construction, architecture for industrial systems and ventilation systems to name a few.

4.6 Concept generation

To decompose the total function into subfunction function-mean modeling was used. As many sub-solutions were derived to each sub-function on the current hierarchical level. To generate a large solution space all subproblems and sub solutions were listed in a morphological matrix. To each subproblem possible sub solutions were listed. Then combinations of solutions were formed by combining the sub-solutions. Early in the process it was clear that there would be a large number of combinations, not only through the number of combinations of sub solutions, but in the way each sub solution could be designed. For example, how many absorbers would a “big fan” provide air flow to? And would there be ducts between each component? Therefore, all combinations that would be unfeasible, unrealistic and with mismatching mass and energy flows were discarded. For the remaining concepts, general sketches with the important details were drawn. The sketched concepts were then evaluated with the help of a Pugh matrix. A reference concept was chosen, which the other concepts were compared to.

4.7 Product architecture.

The three steps in the development process are interdependent as prototyping facilitates and can give indications whether certain modular architecture is possible with regards to given needs and constraints. As some parts of the secondary system are dependent on the level of modularization as well as the design, the integration of necessary components or function was implemented and iterated during the prototyping.

After the screening of the concepts the ones that were not promising were dismissed for further development, decisions about level of modularization were established for the concept with higher potential. The strategy for establishing the architecture will be based on the one presented by Ulrich and Eppinger (2016). The goal is to best satisfy the customer's needs as well as given constraints.

4.8 Prototyping

The purpose of prototyping is to evaluate if the constraints as well as the customer needs can be satisfied with the remaining concept. This regards the fitting of the absorber, shipping, and distance between the pad in the absorber and the fan as well as other components. The level of approximation is rough measurement of primary and some secondary system components for a full assembly. Due to the many anticipated iterations for satisfying the dimensional constraints prototyping was made using CAD design software.

4.9 Clustering of chunks

The clustering of chunks and modularization was exploratory and iterative. The aim was to find the potential benefits of modularity; *product change, product variety, component standardization, product performance, manufacturability, supply chain and postponement*, as well as the product architecture; *Geometric integration and precision, Function sharing, Capabilities of vendors, Similarity of design, Localization of change, accommodating variety, Enabling standardization, Portability of the interfaces.*

The starting point was to assume each function has its own chunk, and chunks were clustered together when beneficial. The clustering started with the absorber as a first element in the soon to be chunk and moving forward from the exhaust air upstream in the opposite direction of the airflow as shown in figure 4.1. Functions and parts were added to the cluster if beneficial. A challenge was to take consideration to the measurement constraints of distance between pad and fan, as well as fitting in the container, while keeping the number of parts to a minimum.

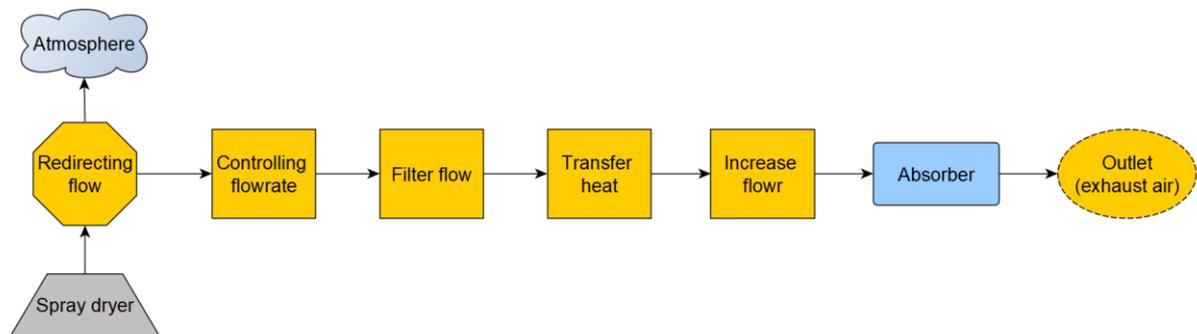


Figure 4.1. Clustering of elements into chunks. Elements can be seen in the airflow from the spray dryer.

5 Results

This chapter presents the thesis results, including findings on customer needs, product specifications, idea generation, concept development, and the final design with a CAD models.

5.1 Product planning

Drupps has already found what they consider as a potential markets and found business opportunities. Although, for the concept development, benchmarking is beneficial for developing a competitive product. As well as a mission statement for the upcoming development to have a clear direction.

5.2 Benchmarking

The benchmarking revealed that, according to Drupps' sales and marketing department, a significant competitor to Drupps' technology is the widespread use of glass tube heat exchangers. However, as can be seen in Table 1, no competitors were identified that utilize evaporative water generation on spray drying exhaust air. Some related products were found, such as Munters' *Quantum Rotor*, which dehumidifies inlet air to improve the quality of the spray drying process, and the *VariMax IFRG* (Munters, n.d.), an industrial heat exchanger designed to handle high temperature air flows, similar to spray drying, for energy recovery. Other technologies identified include fog collection, which captures water from air fog to be consumed as drinkable water (Nioras, 2021). Although, no findings regarding if the technique is combined with the spray drying process was found during the benchmarking. Genaq generates water by condensation, but it is a stand-alone product (Genaq, n.d.). The Alpha Laval Kathabar uses liquid desiccant, like Drupps, but is used for humidity and temperature control in operating rooms (Alfa Laval, n.d.). Alfa Laval Micro is a heat exchanger developed for the process of fuel gas (Alfa Laval, n.d.)

Table 1: Benchmark of similar products.

Company	Product	Evaporative water generation	Recovering heat	Active in Spray drying industry	Related Application or technology
Drupps	Atmospheric water generation	Yes	Yes*	Under investigation	Heat recovery may be possible, further testing will be needed. It is not the company's primary business
Munters	VariMax IFRG	No	Yes	Yes	
Munters	Quantum Rotor	No	No	Yes	Drying inlet air for spray dryers process quality
	Glass tube heat exchanger	No	Yes	Yes	
	Fog collector	Yes	No	No	
Genaq	Atmospheric water generation	Yes	No	No	
Alfa Laval	Kathabar	No	No	No	Liquid desiccant for humidity and air temperature control.
Alfa Laval	Micro	No	Yes	Related	Heat recovery for clean process flue gas

5.3 Mission statement

The mission statement developed for this project clarifies essential aspects of the product’s development, including the product description, benefit proposal, business goals, target market, assumptions, constraints, and primary stakeholders. This finalized mission statement serves as a visual guide, capturing the core objectives and stakeholder requirements for the product.

Table 2: Mission statement.

Mission statement: Evaporative water recovery system

Product description	- Ad-on to recover evaporative water for large flows of humid air from Spray dryers
Benefit Proposition	- Recover water in areas with water scarcity - Reuse thermal energy - Reduce carbon oxide emissions
Key Business Goals	- Payback time of 2 to 3 years* - Environmentally friendly - Propose greater value than current solutions for heat recovery - Fit long-term strategy with three verticals
Primary Market	- Manufacturers using spray dryers - Production is in areas with water scarcity - Manufacturers that are required to reuse water to continue their production
Assumptions and Constraints	- Using the plastic absorber. - Compatible with existing spray dryers.
External Stakeholders	- Purchasers and users - Manufacturing operations - Service operations
Internal Stakeholders	- CEO (long term strategy) - Logistics and Procurement - Sales - Research and Development

*Some of the customers Drupps are in a sales dialog with are mostly interested in carbon dioxide reduction and water recovery, rather the energy savings. Another approach to payback time is needed as the monetary gain from water cost savings is lower than the operational costs of the system. Although the water recovery is crucial for these customers as regulations on water consumption may risk to shut down the company’s operation.

5.4 Customer needs and product specifications

The interpreted needs from the stakeholders’ statements originating from the interview. The interviews can be found in the *Appendix, Interviews with stakeholders*, and a list of interviewees is listed in table 3. The interpreted needs are summarized in a list and organized into a hierarchy in table 4. The relative importance is seated next to each need. The scale spanned from 1 to 5, where 5 is the most important. The product specification shows metric, unit, marginal value and ideal value. Unquantifiable metrics are assigned “subjective”.

Table 3: Interviewees to identify customer needs:

Role	Number of persons
Producer of spray dryers	1
Users of spray dryers	2
Project leaders in energy sector	3
Retailers of spray dryer	1
Retailer specializing in heat exchangers	1
Technicians	5
CEO - Drupps	1
CTO - Drupps	1
CSO - Drupps	1
COO / Logistics - Drupps	1
Sales - Drupps	1
Market - Drupps	1
R&D - Drupps	4

Table 4: Needs and product specifications.

Need	Importance	metric	unit	Ideal value	Marginal value
Safe to operate					
Safe working on heights	5	Subjective			
Technicians can bythemselves secure personal safety when handled dangerous machines	5	Dangerous machines with reachable switches	%	100	Further investigation
Easy to service					
Easy to clean Heat exchangers	3	length of space before heat exchanger	mm	> 1500	> 500
Easy to change filter	5	Subjective			
Plenty of time to perform service	3	Time the system can be shut of	s	0	
Easy access to perform service	4	Subjective			
Easy handling of bulky spare parts	3	space to remove vs biggest component	mm	>100	>0
Perform service comfortably	3	subjective			
Components are reachable independently	3	Components to remove before reaching	Number	0	3
The operation is robust/unsensitive	4				
Ability to perform maintenance and change parts while the system is running.	5	Visualize redirection and independency of flow in chart		Independent	
The system can run with parts of the system stopped due to failing components	5	visualize on flow chart		Independent	
The system is easy to install	4				
Fit current factories footprint	5	Visualize merge drawings	-		
Quick installation	2	Time to install	day	< 5	< 14
Not stopping the manufacturing during installation	5	Time the spray drying process is stopped	s	0	Further investigation
Easy to lift and handle	2	Fit standard lifting equipment	Yes/no		
The system can be implemented and adapted to different customer needs	4				
Fit a variation of customer needs	4	Fit multiple flows	m3/h	15 000 - 250 000	200 000 - 250 000
Ability to make changes with low effort	4	R&D - man hours	h	0	Further investigation
Ability to easily be adapted to different flowrates (Modular)	4	Components possible to use for other system sizes	%	80	20
Ability to use the same components for the other Segments. (Modular)	4	Components possible to use in other segments	%	80	10
Have extra space in confined spaces in case of additional installations of parts.	1	Subjective			
Drupps system never affects the spray drying process					
Stops required during installation	5	Time the spray dryer is stopped due to Drupps system	h	0	Further investigation
Stops required During maintenance	5	Time the spray dryer is stopped due to Drupps system	h	0	Further investigation
No changes to the quality of the inlet air	5	Particles per volume	ppm	0	Further investigation
Easy to produce					
Few different specially designed components	3	Number of designed components	Number	< 10	< 20
Reuse parts and components in the system with variation in flow rates	3	Number of similar components	%	100	50
Use the technology and components that are used in the other verticals	1	Number of components	%	> 80	> 20
Easy testing at (manufacturer hired by Drupps) before shipping					
Ability to assemble the majority of components at manufacturer (manufacturer hired by Drupps).	3	Parts assembled at manufacturer vs. at customer	Number	> 80	>20
Simple assembly	3	Subjective			
Easy to ship					
Fast delivery	3	Fit Standard container size measurements	Use standard	20, 40 foot, high cube	
Low cost for transportation	4	Fit Standard container size measurements	Use standard	20, 40 foot, high cube	
Easy to load when shipped	3	Extra space/wiggle room for components	mm	>200	>100
Easy visualization during sales presentation					
Facilitate demonstration of the system	4	Subjective			
Displaying the main core components to customers in the sale process	1	Visual components	%	100	20
Easy to visualize the scalability of the system to new customers in the sale process	4	Subjective			
Easy to determine cost	1	Time to calculate	min	< 4 min	< 7 min
The system is a good investment					
Low payback time	5	Calculate payback time	Years	2	4
Optimization In size based on the Evaporators capacity.	3	Deviation of flow capacity vs. evaporator capacity.			
Distance between pad and fans	4	Distance	mm	>350 (longer is better)	150

Nuances of the specification.

As stated in the limitation of the scope, the origin of the actual customer is unknown and the laws about safety regulations differ between countries, certain specifications on marginal values regarding for example safety requires further investigation when that information is known.

Figure 5.1. Functional decomposition of Drupps system

5.5.2 Idea generation

Solutions for solving the functions are listed below, the categories are heat transfer systems, and modular structures.

5.5.2.1 Heat transfer systems

Here are the results of heat transfer systems.

Air to air plate heat exchanger

In plate heat exchangers the flow is separated by plates and never mixes. The thermal energy is transferred through the plates. There are different variants of these and in figure 5.2 the one with cross-flow is shown and Figure 5.3 shows one with counter-flow. (uk-exchangers, n.d.)



Figure 5.2 Cross-flow heat exchanger with air flow illustrated (Hoval, n.d.).

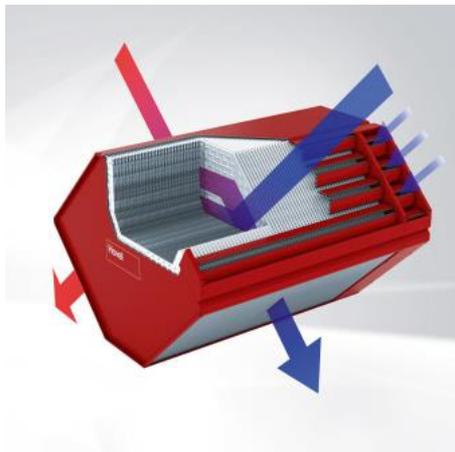


Figure 5.3 Counter-flow plate heat exchanger with air flow illustrated (Hoval, n.d.).

Shell & tube air-to-air heat exchangers

Shell and tube heat exchangers have a shell with tubes inside to separate the flows as can be seen in figure 5.4. Baffles inside create turbulence, which increases the heat transfer.



Figure 5.4. Air-to-air Industrial shell and tube heat exchanger (Pre-heat inc., n.d.)

Rotary heat exchanger

The rotary heat exchanger has large wheels with a honeycomb array, half of which is in contact with the exhaust air and the other half inlet air which can be seen in figure 5.5. The thermal wheel is the most efficient for its size (Zender–Świercz, 2021). Although, cross-leakage, which means mixing of inlet and exhaust flow can occur in all rotary energy exchangers (ASHRAE, 2020).

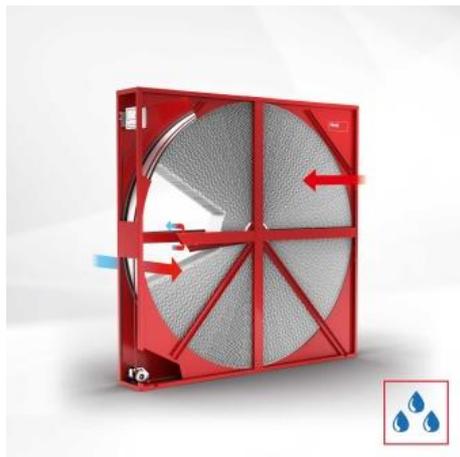


Figure 5.5 Rotary heat exchanger with arrows illustrating the airflow. (Hoval, n.d.)

Tube Heat Exchanger

Tubular-type heat exchangers use a series of tubes to allow the exchange of heat between the two flows. The glass is cheap, can easily be replaced, and has suitable thermal properties. Tubular-type heat exchangers are not as effective at transferring heat as plate types. However, they can withstand higher temperatures, can be made from exotic materials (Irons, 2018)

Finned tube heat exchanger.

The finned tube heat exchanger, shown in Figure 5.6 has a cooling coil and heating coil with fins in the direction of the air flow to increase the heat transfer area. The coils are connected via tubes with refrigerant to transfer the heat between the coils. One coils is placed in the exhaust and the other in the intake. The systems are used where the two air streams are not close enough for more efficient systems such as the thermal wheel or recuperator technology.

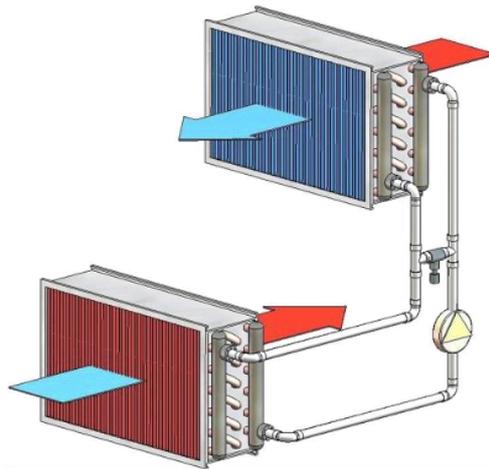


Figure 5.6. Two finned tube heat exchangers connected to each other (The renewable energy hub, 2023).

5.5.2.2 Modular solutions.

In this section results for modular solutions suitable for this project can be found. They come from different industries and also includes smaller standalone constructions that could be assembled before transported.

Modular production line

Figure 5.7 and figure 5.8 shows a modular architecture and connections for adoptable processes. The modular chunks have standardized interfaces to promote variations of total systems. Not all components are required in the configuration.

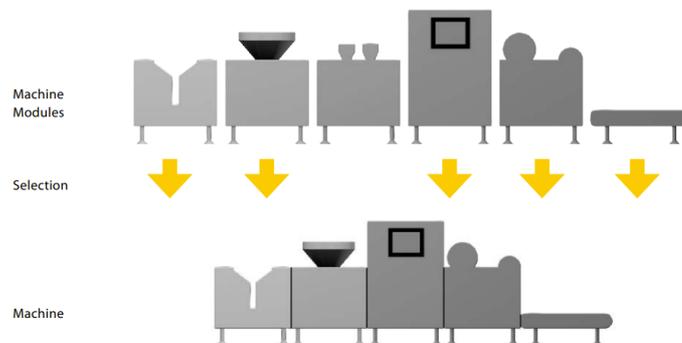


Figure 5.7 shows a modular production system consisting of different chunks (Turck, n.d.)

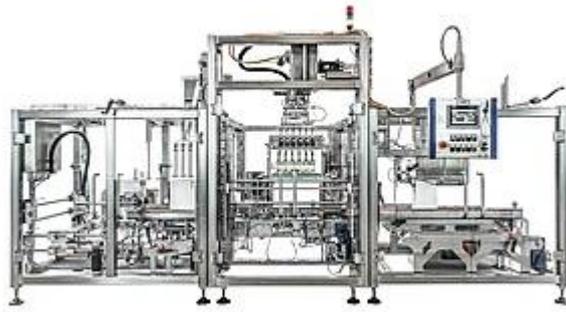


Figure 5.8 A packing system with functions divided into separate chunks (Rico, n.d.).

Modular frames from beams.

Figure 5.9, figure 5.10 and figure 5.11 shows modular frames from beams. The company Metaloq has developed a frame made up of standard beams that are assembled without welding. The frame modules are connected to each other to form a load carrying structure.



Figure 5.9 Metal beams with fasteners that do not require welding (Metaloq, n.d.).



Figure 5.10 Metal frame consisting of beams attached to each other with bolts (Metaloq, n.d.).



Figure 5.11 A ten-story high building is built from frames consisting of beams (Metaloq, n.d.).

Modular ventilation system.

Figure 5.12 shows a modular ventilation system designed to be retrofitted or installed as a new system based on situation and requirements. The modular concept is supposed to make it possible to realize a wide range of performance and air volumes for ventilation.

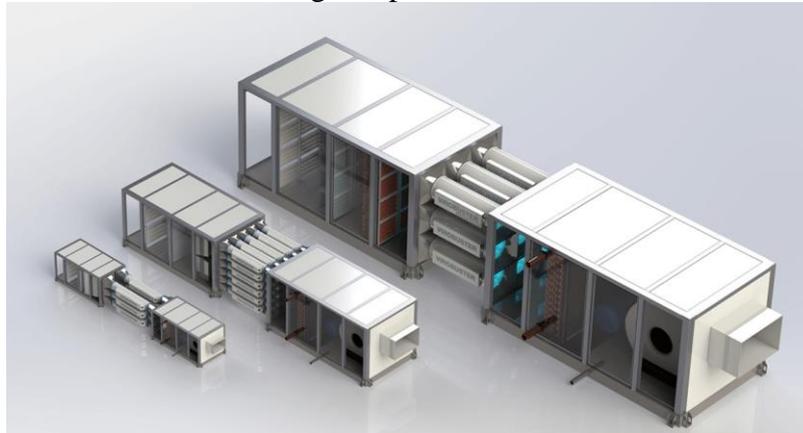


Figure 5.12. Modular ventilation systems with different sections and sizes (IST, n.d.).

Volumetric modular construction for high-rise buildings.

Inspiration for large scale modularization was found in high rise buildings. There are three main construction approaches for stacking volumetric units (Tai et al., 2006.) The first, which is stacking the modules around one or several concrete cores, the concrete resist lateral forces and the modules carry the vertical load. The second is a podium-based method, where the modules are installed on top of a stable platform. This construction is shown in figure 5.13. Thirdly is the infilled frame method where modules are placed within a framing structure. The 3D modules can be classified as a load bearing wall or corner supported frame, where the load is transferred through the edge beams.



Figure 5.13. The modular building Apex house in Wembley, London (Vision, n.d.).

5.5.3 Concept generation

In *Appendix, Function-mean modeling*, the result of from the concept generation and the decomposition of the total function in to subfunctions by using function-mean modeling are shown. The function -mean modeling is then used in the Concept Combination shown in Table 4.

Table 4: Concept Combination Table.

Sub-functions	Sub-solutions				
Hold components	Container as a frame F	Integrated frame E H	Separated Into modules A B C D G		
Enable lifts	Lifting loops in frame A	Forklift holder B D	Loops and forklift C G	Container standards F	No pre-designed frame E H
Lifting spare parts	Vinch B	Elevator H	External crane A C D E F G	Ramp	
Reaching and facilitate removing components	Space in the module/container D E F	Space between each module/container A B C H		Space between two mirrored module/container G	
Adapt to unforeseen needs	Extra space inside module A C E F H	Build in different sizes B D G	Add extra module if needed		
Hold filter	In the duct A G H	In contruction B C D E F			
Construction arrangement	Wall A B E F G	House C H	Surrounding U-form D		
Stop flow	Multi-balde backdraft B F G H	Valve A D	Garage port C	Shut of the process E	Redirect flow
Filter type	Rolling filter, automatic filter A	Bag filter B C D E F G H			
Transfer heat	Run around coli A B C D E F	Rotating H	Plate G		
Clean heat exchangers	Extra space for cleaning (brush and liquid) C D B E G H	Install automatic cleaning with water A			
Secure Spray drying process	Redirect flow with duct E F G	Redirect flow with fans A B C D H			
Secure function during intsalation	Stop production	Enough spacing between systems C D E F H	Spacing with extra fan as help A B G		

Result of generated concepts:

Concept “A” - “Automatic filtration in duct”

This concept has an automatic filter and heat exchanger placed in the duct before the absorber as can be seen in figure 5.14. The duct widens and lets the flow reach several absorbers facing the flow. There is a fan before the filters to redirect the flow to prevent affecting the spray dryer process in case of unforeseen stop in the Drupps system.

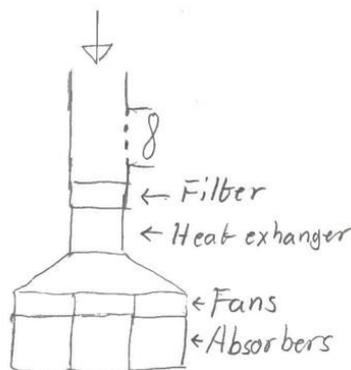


Figure 5.14. Concept “A”, named “Automatic filtration in duct”.

Concept “B” - “Modular wall - individual modules”

The duct widens and faces a wall with all inlet modules connected with a series of valves, filter, fan, heat exchanger and absorber in series which is shown in figure 5.15. The valve lets each module series be serviced individually by closing that particular valve. Each module is connected to a platform that goes alongside the modules to access the modules individually. The inlet and outlet modules are connected through piping to transfer the heat between the heat exchangers.

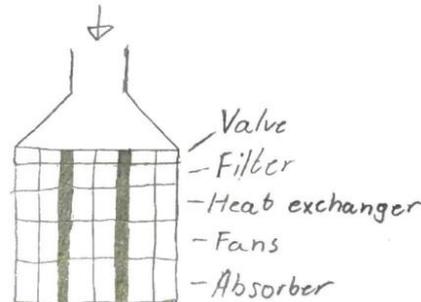


Figure 5.15. Concept “B”, named “Modular wall - individual modules”

Concept “C” - “The house”

In figure 5.16, concept “C” is illustrated with modules of filter, fan, heat exchanger and absorbers are surrounding the airflow which is directed by ducts to enter the middle of the modules. The ducts pass underneath the surrounding walls. The air flow is directed upwards. A fan is mounted on the top of the construction to prevent back pressure in the spray dryer in case the Drupps system fails.

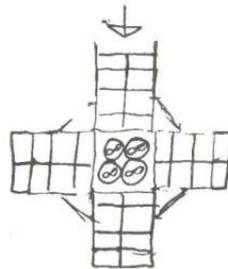


Figure 5.16, concept “C”, named “The house”.

Concept “D” - “Surrounding module”

Modules are surrounding the airflow as figure 5.17 displays. This concept also has a connection to the heat exchanger in the inlet module via piping. In case of stop this concept also has a fan up top to redirect the airflow.

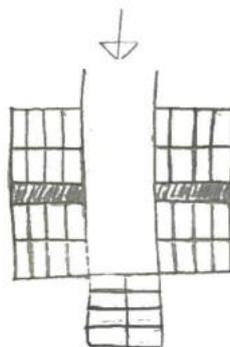


Figure 5.17. Concept “D”, named “Surrounding module”.

Concept “E” - “Big fan”

For this concept the size for the fan is enlarged to provide flow for 4 absorbers and one large heat exchanger replaces 4 smaller ones as can be seen in figure 5.18. That is connected to a large heat exchanger placed on the inlet to the spray dryer. Note that the size has to be dimensioned for the specific outlet flow of the spray dryer for that particular customer. The size of the absorbers remains the same.

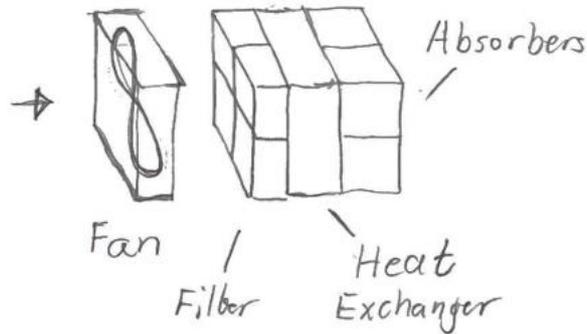


Figure 5.18. Concept “E”, named “Big fan”

Concept “F” - “Wall container”

In this concept which is illustrated in figure 5.19, a container is used as a frame that can support weight, protect the component and be shipped as it is. The container is then placed in the formation of a wall and the ducts are connected to the container openings on the short side of the container. The heat exchangers in the inlet and outlet have to be connected.

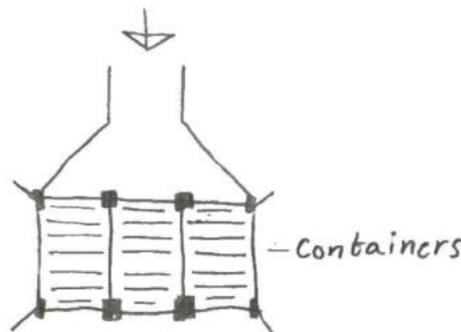


Figure 5.19. Concept “F”, named “Wall container”.

Concept “G” - “Close ducts - mirrored modules”

This concept has the filter and heat exchanger in the duct and separated from the fans and absorber. The heat exchanger is a plate heat exchanger which implies that the inlet and outlet duct has to be beside each other. Therefore, the duct from the inlet and outlet from the spray dryer has to be connected physically to allow the heat exchanger to function. Two modules are also placed next to each other with platforms at the ends, this allows for less drag if only two in a row is needed and if four needs to be placed in a row, only one platform module will be in the duct. A drawing of the concept is shown in figure 5.20.

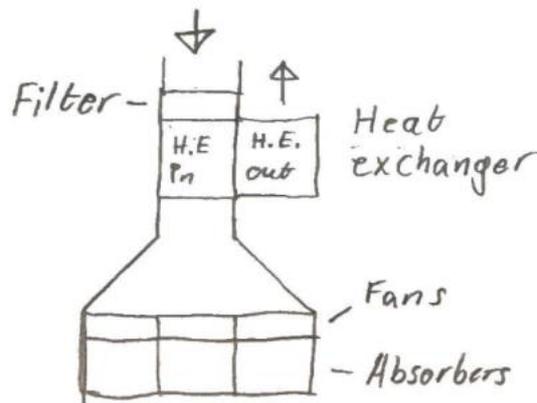


Figure 5.20. Concept "G", named "Close ducts - mirrored modules".

Concept "H" - "Close duct - surrounding house"

This concept also has the filter and heat exchanger in the duct and separated from the fans and absorber which can be seen in figure 5.21. The heat exchanger is a rotary heat exchanger, therefore the inlet and outlet duct have to be beside each other. The structure is a mezzanine with the necessary components placed in. It is built at site from beams and has the house- shape as concept "The house".

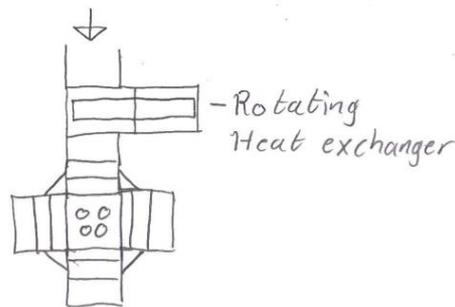


Figure 5.21. Concept "H", named "Close duct - surrounding house".

5.5.4 Concept evaluation

The "Modular wall" concept was chosen as reference as it was one of the most straight forward concepts.

Table 5: Concept evaluation

Phug no. 1	Concepts							
	B	A	C	D	E	F	G	H
	Modular wall - Independent modulas	Automatic Filtrater in duct	House	surrounding moduals	Big fan	Wall containers	Close ducts - mirrored moduals	Close duct house - one big frame
Selection criteria								
Reachable Components		0	-	0	0	-	0	0
Easy to change filter		+	0	0	-	0	0	0
Easy to Operate		-	0	0	0	0	0	0
Installation		0	0	0	0	0	0	0
Physical footprint		0	+	+	0	0	0	0
Flexible component placement		+	0	+	-	0	0	0
Simple installation		0	0	0	-	+	-	-
adaptable to fit variation of needs		0	0	0	-	-	0	0
Reuse of components		-	0	0	-	-	0	0
Shipping		0	0	0	-	0	0	0
Simple assembly at sight		0	0	0	-	-	0	0
Outsource manufacturing		0	0	0	0	-	0	0
Same moduals for other flowrates		-	0	0	-	0	-	-
Same moduals for other segments		0	0	0	-	-	-	-
Sum +	0	2	1	2	0	1	0	0
Sum 0	0	9	12	12	4	7	11	11
Sum -	0	3	1	0	9	6	-3	3
Net score	0	-1	0	2	-9	-5	-3	-3
Rank	2	3	2	1	6	5	4	4

The concept "surrounding modules" had the highest score and ranked the best. It was considered to have a lower footprint due to the benefit of using a smaller area for installation than the other concepts. The components or parts of the system could also be altered more easily, for example by having a longer wall on one side of the airflow than the other, the middle

part could also vary in length. Although looking at the outcome of the Pugh matrix, each concept had different strengths and weaknesses regarding the criteria. This gave the opportunity to combine features that were considered beneficial into a new concept. New ideas arose about not limiting the arrangement, and instead allowing different types of installments with the same parts. Two new concepts were formed by what was considered to be good features,

5.5.5 Iteration for improvements

The two following concepts are a combination of the previous concepts. The new idea about not limiting the arrangement in the installation was implemented in the second concept.

Concept “I” - “24/7 operation”

The idea for the concept is to be able to collect air by atmospheric water generation straight from the ambient air even when the spray drying process is not running. The idea came from the design of separating the filter and heat exchanger from the fan and absorber. By opening the duct and having enough space to let ambient air flow through the space between the heat exchanger and fans, which are illustrated in figure 5.22, the fan and absorber could be used as a separate unit, independent of the spray drying process. This would be beneficial for the customer with a high downtime in their spray drying process.

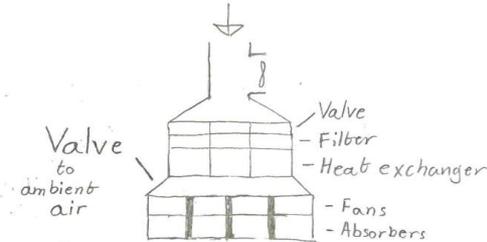


Figure 5.22 Iterated concept “I”, called “24/7 operation.”

Concept “j” - “Modular and shapeable”

The concept is shown in figure 5.23 and was inspired by the combinations of different arrangements, the modules in the concept have well defined interfaces which allow all previously displayed arrangements. It is similar to “Surrounding module” but with the improvement of having easy access to components by having platforms to reach the individual modules. Each module is similar in size to facilitated new arrangements. The goal with the concept would be to fit more factory sites and the customer could early in the sales process see if a rearrangement would fit their specific space constraint.

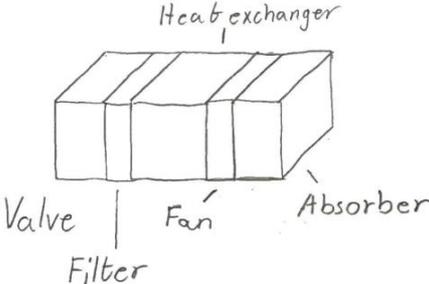


Figure 5.23. Iterated Concept “j”, named “Modular and shapeable”.

The new combined and improved concepts were added to the Pugh matrix evaluated against the same reference. The concept “Modular and shapable” scored the best and was therefore continued with further in the developed process. It could fit a variation of need due to the high modularity allowing it to be more precisely adopted to a specific flow rate and also to not use

components needed for a specific installation. The physical footprint and flexible component placement was also better than the reference due to the same arguments as the surrounding modules as it could be formed and mimicked in to that chape as well.

Table 6: Pugh Matrix

Flng no. 2		Concepts								
Selection criteria	Modular wall - Independent modules	Automatic Filtrater in duct	Honse	sourrounding moduals	Big fan	Wall containers	Close ducts - mirrored moduals	Close duct house - one big frame	Water 24 / 7	Modular shape
Reachable Components		0	-	0	0	-	0	0	0	0
Change filter		+	0	0	-	0	0	0	0	0
Operation		-	0	0	0	0	0	0	0	0
Installation	R	0	0	0	0	0	0	0	0	0
Physical footprint	e	0	+	+	0	0	0	0	-	+
Flexible component placement	f	+	0	+	-	0	0	0	0	+
Simple installation	e	0	0	0	-	+	-	-	0	0
Fit variation of needs	r	0	0	0	-	-	0	0	+	+
Reuse of components	e	-	0	0	+	+	0	0	0	0
Shipping	n	0	0	0	-	0	0	0	0	0
Simple assembly at sight	c	0	0	0	-	-	0	0	0	0
Outsource manufacturing	e	0	0	0	0	-	0	0	0	0
Same moduals for other flowrates		-	0	0	-	0	-	-	0	0
Same moduals for other segments		0	0	0	-	-	-	-	0	0
Sum +	0	2	1	2	0	1	0	0	1	3
Sum 0	0	9	12	12	4	7	11	11	12	12
Sum -	0	3	1	0	9	6	-3	3	1	0
Net score	0	-1	0	2	-9	-5	-3	-3	0	3
Rank	3	4	3	2	7	6	5	5	3	1

5.5.6 Product architecture and clustering of chunks

Absorber and Fan

One constraint was to use the newly developed plastic absorber; therefore, it was imported into a CAD-model of a standard container to see how to fit as many as possible in one container while having a frame around it which could support weight and the whole structure, (called main frame from now on). Two absorbers could fit length wise in a container and still have the needed room to be load the frame in and out of the container. The free space between one absorber and the container wall in the width-dimension gave potential to either fit another absorber, or cluster with the fan.

The width of the main frame was then maximized with regards to the assumed space needed to be loaded in the container and the fans was assembled with the absorber to measure the constraint of distance between the absorber and fan for optimal air distribution. Both constraints were able to be fulfilled. The height of absorber with connecting pipes was too short for a standard container but could fit in a standard “high cube container” while satisfying the needed loading space height-wise. The heat absorber and the fan were a suitable match to cluster together considering the mentioned measurement constraints.

Heat exchanger

Moving on to the next function in the flow chart. First, a new frame for the heat exchanger was designed, but realizing the measurements were similar to the previous main frame, the idea of using the same measurement would create fewer different frames. The heat exchanger could fit in the same sized main frame as the absorber and fans did. When adding the filter next to the heat exchanger, together in the same sized main frame, the space constraint for cleaning was not sufficient.

The design choice now rose with the first alternative to use two main frames of the same size and put the heat exchanger in one and the filter in the other. The second alternative would be to adjust the size of the main frame. Changing the size would mean more parts and making it bigger would result in not fitting two main frames together in one standard container.

Using the exact same main frame would be beneficial as the main frames could be standardized and attached to each other with sectional modular connection. This is further explained in an

upcoming chapter. So, keeping the idea of standardizing in mind and the possibility of using the same main frame, as well as knowing no extra space was available towards the absorber and fan module, the heat exchanger was not clustered with any other function or component, as the next section will explain and confirm why it made sense not to cluster the heat exchanger.

Filter

Continuing the idea in the previous section, the filter was placed in the same sized main frame with the needed distance for cleaning the heat exchanger. The required distance could be satisfied and allowed the vent to be clustered together next to the filter in the same chunk.

When attaching the filter and heat exchanger chunk next to each other, it was sufficient space for cleaning the heat exchanger and the operator could move between the modules, given the space needed that the lead user for heat exchangers suggested.

The results of the clustering of the components are shown in figure 5.24, where the lined squares represent the chunks containing the designated components in a flow chart. The CAD rendering is shown in figure 5.25, including the same components, but assembled in main frames. The three chunks are assembled in the same order shown in figure 5.24. The CAD model was used to measure, adjust, and rearrange the components while clustering and designing the new components. The most left chunk, *Duct* is for redirecting the flow form the spray dryer to the AWG system, and is not shown in the CAD model as the chape is dependent on the interface of the spray dryer and the size of the total AWG system.

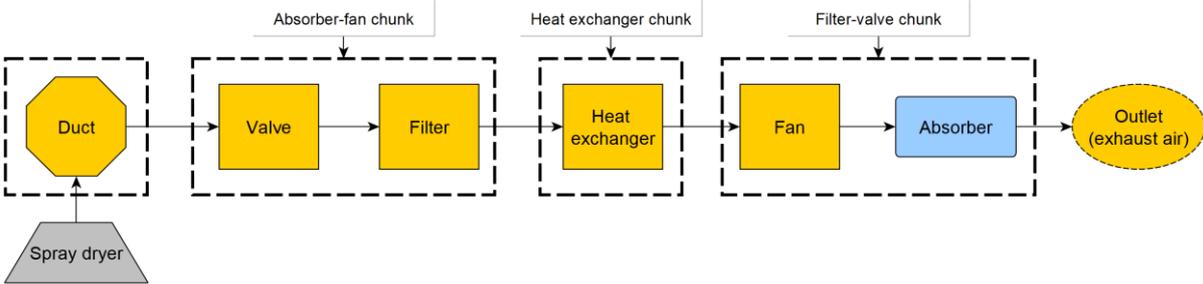


Figure 5.24. Chunks represented by lined squares consisting of components shown in a process chart layout.

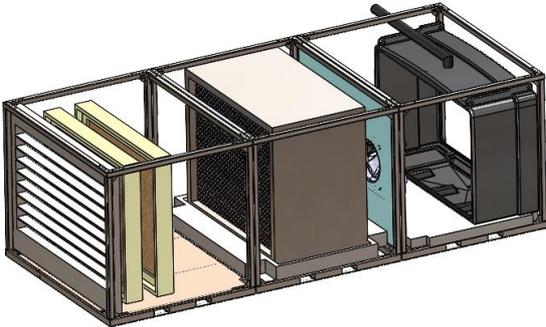


Figure 5.25. A CAD model with Absorber-fan chunk, heat exchanger chunk and Filter-valve chunk assembled.

5.5.6.1 Secondary system

The primary functions of the secondary system that was within the limit of the scope was:

- Hold components such as fans, walls, floor, and physically access the components.
- Separate the flow between one of each module to form the smallest possible system.
- Allow access to reach components.

These parts were designed simultaneously as the main frame and modularity for the whole system. Therefore, the beneficial factors are explained for each part.

Main frame

As mentioned before, the height of the main frame was maximized while still fitting the constraint of being loaded into a standard container. The maximized height was necessary to fit the absorber inside the main frame and still have room for the connecting pipe to the absorber as well as improve the ergonomics for the technicians. Although this left no room to pile up the main frame from the ground to facilitate lifting, instead forklift-compatible holes were integrated in the lower beam. To prevent any damage to components inside the main frame, square tubes were connected to the two additional beams on the bottom of the main frame. By using the same thickness on the added beams, the bottom beams should support loads of component installed inside the main frame as well as the weight of technicians walking inside the main frame performing service. A CAD model of the main frame is shown in figure 5.26. The mirrored design allows lifting from both sides and allows the same main frame to be used in a larger assembly, this can be seen in the assembly of two minimal systems.

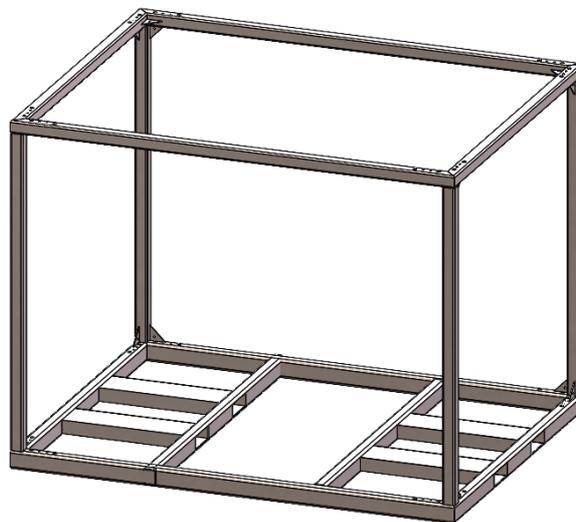


Figure 5.26. The main frame. Measures: Width: 2860mm, Depth: 2200mm, Height: 2240 mm.

Door / Wall

To separate the flows between the frames some type of separation of flow was needed. The main frame also needed to withstand lateral forces and by adding a wall, seen in figure 5.27, to the main frame it could both separate the flow and add structural support. The wall carries multiple functions, carrying load, enables access inside the construction and separates flow,

potentially reducing material and components. To hold the wall attachments were added to the side corners of the main frame.

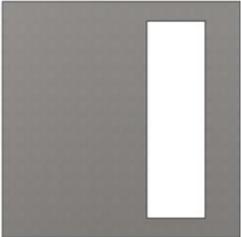


Figure 5.27. Door / wall

Both the door and wall have the same bus-modular interface to the main frame. When assembling the three module frames with the rest of the components in place and in the order, they are supposed to be installed there was an opportunity to design walls with entry to the modules with the same measurements if just mirrored. That was an opportunity to design a standard interface for the walls that would allow for only one wall to fit both sides of all three modules. The wall is then sealed by a sealing to the door, which is to be placed in the hole, and could be mounted from both sides of the wall, by having one version of the wall to fit both sides of the modules, the number of varying components is reduced.

Fan adapter

To hold the fans and direct the airflow through the fans a fan-adapter shown in figure 5.28, was designed. The fan adapter holds the weight of the fans as well as attaching the fans to the main frame. The same type of fasteners for the door/wall is used to hold a sheet with holes to fit a fan. The sheet also provides structural support for the main frame.

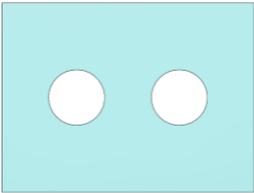


Figure 5.28, Fan adapter

Floor

The floor illustrated in figure 5.29 is attached on top of the beams on the bottom of the main frame to provide support to walk and stand on.



Figure 5.29 Floor to be attached on the main frame

“Fasteners” between chunks.

To include the necessary component and attach the main frames to each other, in all directions, in front of, behind, to the sides and above and below, three different fasteners were designed to be able to accomplice all configurations, regardless of number and position of main frames.

The three different module connectors shown in figure 5.30 along with standard bolts enable assembling the entire structure of main frames.

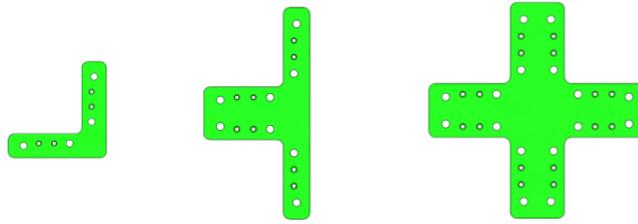


Figure 5.30 the fasteners connecting the main frames together

Inspiration was taken from the skyscraper fasteners, the V- formation was considered the most promising one. With modifications it could connect four modules in each corner with a newly designed part formed as a cross.

5.6 Final design

In this chapter the conceptual design presented should be seen as a first iteration of a new potential platform concept. Each chunk is described as well as how the different chunks form a system. Also, how modular architecture can be used to form not only the targeted flowrate but also lower and higher, as well as cover the other strategic business areas.

The benefits of clustering and modularization is described, both for each individual chunk but also the whole architecture and combination of chunks, with respect to components, function, how the design is to be tested at factory, shipped, installed and variations of arranging the modules to fit customer needs and space constraints is presented.

5.6.1 Main modules

In table 7 and table 8, the Bill o Material is presented, with the three chunks, Absorber-fan chunk, heat exchanger chunk and Filter-valve on the left column, the components in the middle column and the quantity of each part on the right most column. The three chunks can be added in the series to combine three different types of products, HEAT, SCRUB and ATMO. By adding several units in parallel the installment can be adapted to variations of flow volumes.

Table 7: Bill of Material for HEAT and SCRUB segment

Bill of Material for HEAT and SCRUB-segment		
Chunk	Component	Quantity
Absorber-Fan	Main frame	1
	Absorber	1
	Fan adopter	1
	Fan	2
Heat exchanger	Main frame	1
	Heat exchanger	1
Filter-damper	Main frame	1
	Valve	1
	Filter	2

Table 8: Bill of Material for ATMO segment

Bill of material for ATMO-segment		
Chunk	Component	Quantity
Absorber-Fan	Main frame	1
	Absorber	1
	Fan adopter	1
	Fan	2
Filter-damper	Main frame	1
	Valve	1
	Filter	2

5.6.1.1 Absorber-Fan Chunk assembly

The fan absorber chunk shown in figure 5.31 consists of the one main frame, the absorber, fan adapter and a fan. The walls are left out to better see the components inside the chunk.

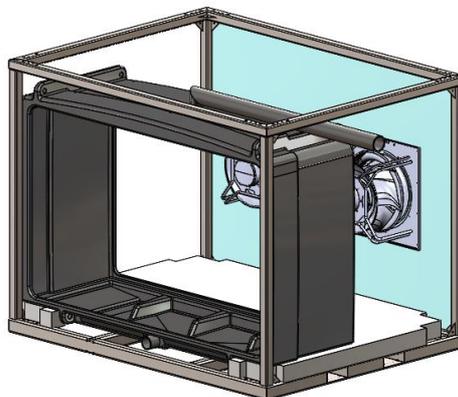


Figure 5.31 The absorber-fan chunk.

Chunk specific benefits with the modularization:

Product change

There is a risk the fan needs to be changed due to change of supplier, change in filters or heat exchanger causing higher back pressure requiring a more powerful fan, downsizing for energy efficiency, it can easily be done by changing the fan and the fan adapter. The fan adapter is therefore a simple removable component isolating the fan from the main frame and the only part needed to be changed to alternate the fan allowing for simple redesign of the flat sheet panel to fit other fans or even other number of fans that would fit on the surface area. This would allow the main frame to remain the same because it is the only interface towards the fan. The system has a long-anticipated lifetime, and the fan can therefore be changed to a updated one or bought locally by any manufacturer.

Product variety

Countries have varying electrical standards, requiring specific voltage and frequency specifications for the fans. Some customers may prefer a particular fan model if it aligns with the existing fans used throughout their facilities, as this simplifies maintenance and spare parts management. If a fan is found to be incorrectly dimensioned after a complete installation, it can be easily replaced with another model without the need to disassemble or alter the main frame, enhancing flexibility and reducing downtime.

Supply chain and postponement.

The postponement can be affected here by assembling all components except for the fan and fan adapter which could be decided last. The design allows to install those components last in the assembly order.

Capabilities of vendors.

This chunk can be tested in the factory where it is assembled to ensure quality. By clustering the absorber and fan the unit could also be tested at the manufacturer which was brought up in the customer needs. A test rig with sensors could see if the chunk could perform a satisfactory distribution of air over the pad area as well as sufficient air pressure from the fans, it would make sense to test all functions at the same time at this chunk allows that. Figure 5.32. showing a idea of how the test rig could look.

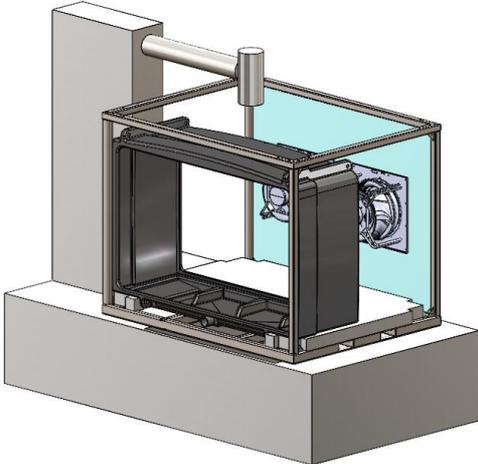


Figure 5.32 Idea of testing for factory acceptance test.

5.6.1.2 Heat exchanger Chunk assembly

The heat exchanger chunk is shown in figure 5.33 consists of the one main frame and a heat exchanger. The walls are left out to better see the heat exchanger inside the chunk.

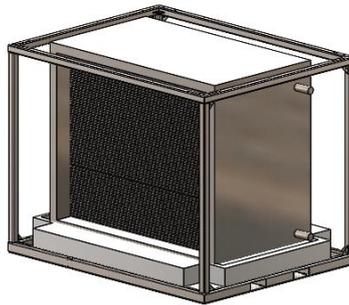


Figure 5.33 The heat exchanger chunk.

Chunk specific benefits with the modularization:

Product change

The main frame is designed to accommodate various heat exchanger models, manufacturers, and fin configurations, allowing for significant flexibility in product choice. Similar to the fan selection, certain customers may prefer a specific heat exchanger model, while others may require food-grade materials to meet regulatory standards. Additionally, the adaptable design anticipates emerging needs as the market evolves, imposing minimal constraints on compatible models. In Figure 5.33, a heat exchanger is installed inside the main frame. Due to the sectional-modular interface, two main frames with heat exchangers could be mounted in series if the heat transfer of one heat exchanger would not be sufficient.

Product variety

The cost of assembly would not be affected by a change of heat exchanger, which is beneficial due to the uncertainty in model choice. The dimensions for the heat exchanger will most certainly vary and by not integrating the heat exchanger it can easily be replaced. Reasons for changing models could be risk of clogging, material suitable for cleaning, heat transfer performance or backpressure.

Supply chain and postponement.

The choice of the heat exchanger may have a large impact on the performance as well as the serviceability of the system. By being able to choose the heat exchanger late, the rest of the system can be manufactured in advance without affecting the final configuration of heat exchanger.

5.6.1.3 Filter-valve Chunk assembly

The filter-valve chunk shown in figure 5.34 consists of the one main frame, a valve, and filters. The walls are left out to better see the filters inside the chunk.

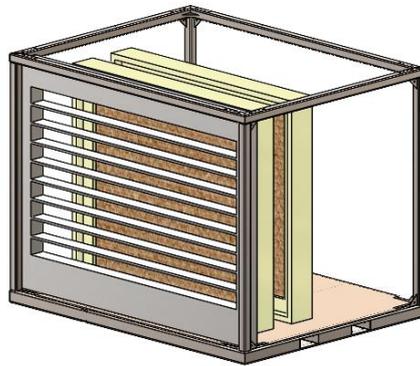


Figure 5.34. The filter-valve chunk.

Chunk specific benefits with the modularization:

Product change

The filter is an isolated functional element in this chunk and could therefore easily be changed, this is an element exposed to wear and will need to be changed with regular intervals depending on the particles in the flow. Depending on the particle size, different filters will be needed. The change of filter associated with maintenance as well as assembling different filters is facilitated by the isolated interface and large physical space to reach the filter.

Product variety

Different types, number and manufacturer of filters could be used and not affect the assemble order or needed space.

Component standardization

The fastener in the corner of the main frame used for holding the adapter to the fans uses the same interface to attach the duct valve, this reduces the number of components, and allows for only one main frame.

Supply chain and postponement.

The choice of the filter may have a large impact on the performance due to variation in particle sizes in the residual air from the customer. Some may even require chemical filters. The filter size will also affect the serviceability of the system due to the intervals of the filters will gain unacceptable high back pressure. By being able to choose the filter late, the rest of the system can be manufactured in advance without affecting the final configuration of heat exchanger.

5.6.1.4 Common beneficial factors for the parts in all chunks considered.

Product change

The main frame is the core of the product architecture, and many other parts are dependent on its design and interface. Although, some parts have an extra part attached between the main frame and the function carrying element, such as the fan and the fan adapter. The design of the main frame is therefore of great importance because changes in the main frame will affect many other parts and dimensions.

Product variety

The walls also may be produced of the same material and production technology, increasing customer adaptation as well as allowing a larger number of potential producers of the part.

The uncertainty in requirement for filters will not affect the current design as plenty of physical space is left for variations of filters.

Component standardization

It was not obvious that the main frames would be of the same size, but the benefit on having the same size on all frames, Main frame, reduced the number of different parts. As mentioned in the 5.3.6 *Product architecture and Clustering of chunks*, the absorber-fan chunk became driver of the dimensions. Due to the one sized main frame as well as the same interface for the wall & fan adapter, the number of parts can be reduced dramatically, hence benefiting the logistics and required stock. Only one type of door needs to be produced, to fit both the Absorber-Fan Chunk, and filter-valve chunk, which are described below.

Function sharing

The functions of the main frame, - supporting weight for walking, holding other components, supporting lifting, and protecting components, are all highly integral in this element compared to the overall modular architecture. The main frame was designed to fulfill these functions and benefited from *function sharing*, the functions; providing structural support, holding components, carrying the load for walking on the floor of the frame, protecting components during shipping, and facilitating lifting.

The door/wall & fan adapter has the function of separating the airflow within the unit from the outside air. It also contributes to the structural support, much like the walls of a container. The door/wall therefore also benefits from *function sharing*, by combining structural support and separation of flows.

Capabilities of vendors

The Filter-valve chunk has the filter and valve element which may be an advantage because one vendor likely can provide both components.

5.6.1.5 Modular connections

The main frame was designed to make the whole Drupps system into chunks with sectional-modular connections between the chunks due to the wide variety of configurations. The same bus- modular interfaces were designed for the walls and door, as well as the fan adapter and the duct, allowing for all configurations to fit the same main frame. Slot modular connections were designed for the filters and heat exchanger due to the specific properties and the low level of variation. The three main modules are the result of the need caught in the thesis, although the interface of the main frame has the potential to answer future needs.

5.6.1.6 Minimal unit

By Assembling the three Absorber-fan, heat exchanger and filter module in series as shown in figure 5.35 the smallest complete system for handling spray drying residuals is formed. It has the necessary components for the parts within the scope of the project. The limiting component

is the absorber, which can handle between 20.000 and 25.000 m³ air per hour with an increased backpressure as a result of a higher volume flow. The picture shows the smallest standard system with one of each chunk. This structure will be on top of, or next to the rest of the needed Drupps system i.e. the buffer tanks, pumps and evaporator. The size of the buffer tanks, pumps and evaporator will be sized based on the flow and content, but physically independent of this part of the system except for the connecting pipes.

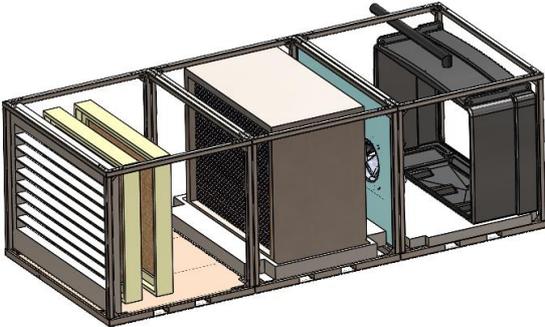


Figure 5.35. Assembly of each chunk in series forming the smallest system with the necessary components.

Figure 5.36 shows an earlier concept of Drupps system for atmospheric water generation, the buffer tanks in the middle will remain but the mezzanine and old absorbers will be replaced by the new concept.

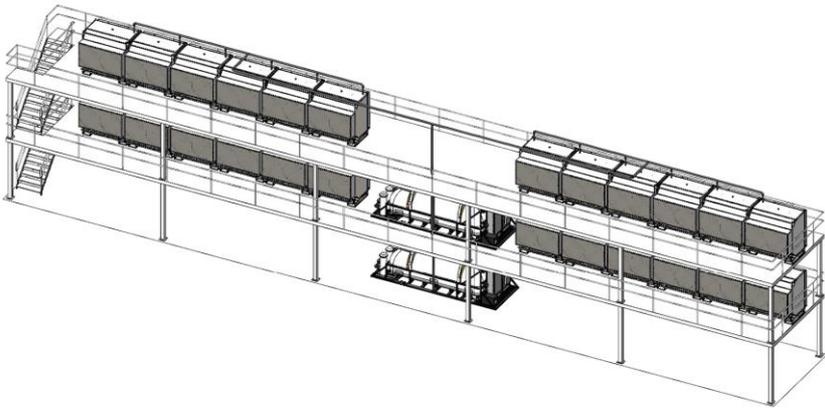


Figure 5.36. Earlier concept of Drupps system for atmospheric water generation. Buffer tank is shown in the middle.

5.6.1.7 Units for alternative flowrates

By adding two minimal units next to each other and connecting empty main frames with floors on each side of the two minimal units, as seen in figure 5.37, the airflow of residual air from the spray dryer can be doubled. Note that the system is not shown from the same angle and the walls are not assembled to have a better visualization.

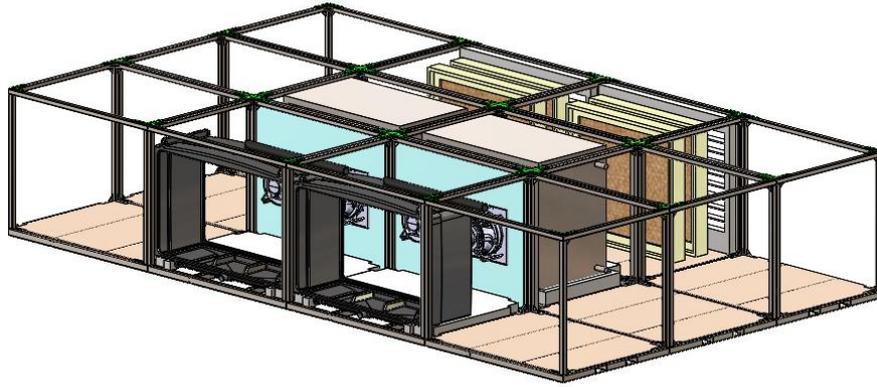


Figure 5.37. assembly of two minimal units and platforms on the sides.

To increase the capacity even more, several minimal units can be stacked on top of each other and connected to the same platform made from the main frame. The reason for placing only two minimal units next to each other is to be able to change spare parts and service each unit individually without cutting the flow for any other unit except the one to service, this is further explained further down.

Figure 5.38 shows another possible assembly containing eight minimal units assembled with extra main frames on the sides to form a platform on each side to reach the components inside the chunks. The platform is just a floor part attached on top of an empty main frame and supported by the main frame.

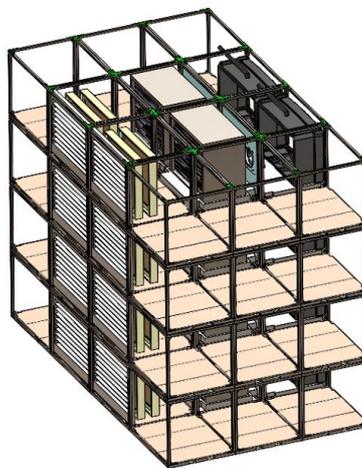


Figure 5.38 An assembly variant of eight minimal units.

5.6.1.8 Unit for target flow

The primary target was to design a system that could handle an airflow of 300 000 m³ /h. Figure 5.39 shows twelve connected minimal units for the spray drying application. The minimal units are connected in pairs, stapled on top of each other and in an angle with the fronts connected and a platform attached to enable access to reach each chunk without having to stop the operation of more than that specific chunk when servicing. To handle larger flows, more minimal units can be connected next to each other and stacked on top of each other.

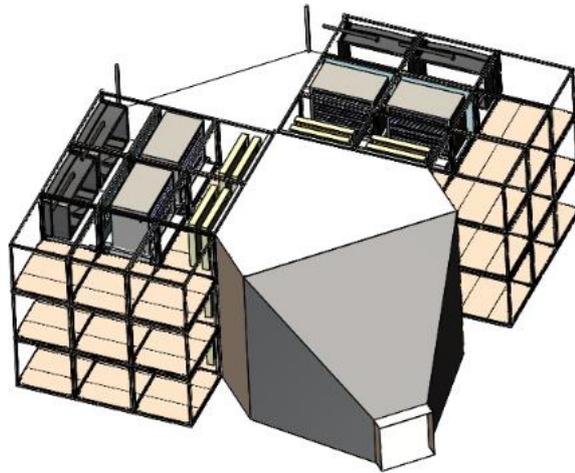


Figure 5.39. Twelve connected minimal units with an connecting eccentric duct enlarger directing the flow from the spray dryer to Drupps system.

5.6.2 System and modularity

Since no system has been sold yet and the exact customer is unknown, it is a high uncertainty project, and the customer need may vary a lot, therefore it is beneficial to be able to make changes to the design without having to redesign everything. This chapter will present how the modular product architecture is designed to be adopted to unknown needs and align with Drupps strategy and targeted business segments with different needs. Both within the spray drying segment e.g. flow rate and content of the flow as well as the other business segments.

5.6.2.1 Product variety

The module system interface allows for more modules to be added in series. If new needs arise extra modules with, for example, scrubbers can be added. If it is a onetime need the add-on can be engineered to order or if it is anticipated to be several customers with the same need and the extra equipment is too large to fit in the main frame, the same interface could be used to connect a longer version of the main frame. variants of the product can be designed to meet currently unknown need by adding another main frame to the assembly. in the current unknown market, the design allows for changes both in volumes as well as specific component in the system.

5.6.2.2 Business segments

The three business segments have different technical specifications and different components. During the clustering of the chunks, the three business segments were considered. In the ATMO segment, the heat exchanger is not included in the system and in the SCRUB segment evaporator is excluded. By taking advantage of the well-defined interface, the same components can be used for all three segments. Even more main frames could be added, and modified with varying size if the new function requires a component that does not fit.

ATMO-segment.

This system is without the heat exchanger. The absorber-fan chunk as well as the filter and duct chunk are assembled in this configuration. Due to the sectional-modular interface, the heat exchanger chunk can be removed, and the other chunks attached together forming the minimal unit for the ATOM-segment as can be seen in figure 5.40. With the same principle as the previously shown larger systems, this can also be assembled into larger systems to handle larger flows.

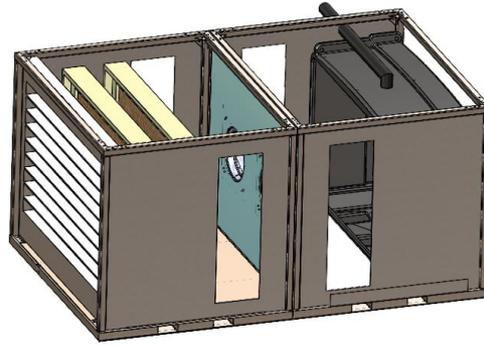


Figure 5.40. Assembly for the minimal ATMO-segment.

SCRUB- segment.

This system is without the evaporator, which is included in the part of the system that is outside the project scope, so for this segment the same minimal unit would be used as in the spray drying application.

5.6.2.3 supply chain and postponement.

Shipping

Two main frames fit in a standard high cube 20 feet shipping container, with inside measures: 5,89 meters in length, 2,35 meters in width, 2,7 meters meters in height, with 75 mm extra space on each side. The holes on the bottom are designed to be lifted with a standard forklift. The main frame will serve as protection around the components when shipping and loading in and out of the container as the main frame covers all corners and edges. The chunks will be shipped fully assembled but for illustration purposes, two empty main frames are shown in the container in figure 5.41.



Figure 5.41. Two main frames loaded into a standard high cargo container.

Delayed differentiation

Due to the similarities in the segments and the modularity in design, there is a benefit of delaying the differentiation until late in the supply chain. This may offer reductions in the costs of operating the supply chain, due to reductions in inventory requirements. The differentiating elements may be the filters and heat exchanger within the chunks for all three segments which are concentrated to the heat exchanger and the filter-duct-chunk, which are easily assembled late in the supply chain. The rest stay the same. For the SCRUB-segment the only difference is that the heat exchanger chunk is excluded.

5.6.3 Customer needs fulfillment.

In this chapter the customer needs and specification fulfillment are discussed, and how the needs should be evaluated if they cannot be determined at this point. A comment is associated with each need as seen in table 9 and are listed below with further explanation.

Table 9 table showing needs fulfillment and associated comment number.

Need	Importance	metric	unit	Ideal value	Marginal value	Needs fulfillment	Comment
Safe to operate							
Safe working on heights	5	Subjective				Needs further investigation	1
Technicians can by themself secure personal safety when handled dangerous machines	5	Dangerous machines with reachable switches	%	100	Further investigation	Needs further investigation	2
Easy to service							
Easy to clean Heat exchangers	3	length of space before heat exchanger	mm	> 1500	> 500	Fulfilled	3
Easy to change filter	5	Subjective				Needs further investigation	4
Plenty of time to perform service	3	Time the system can be shut of	s	0		Fulfilled	5
Easy access to perform service	4	Subjective				Fulfilled	6
Easy handling of bulky spare parts	3	space to remove vs biggest component	mm	>100	>0	Fulfilled	7
Perform service comfortably	3	subjective				Fulfilled	8
Components are reachable independently	3	Components to remove before reaching	Number	0	3	Fulfilled	9
The operation is robust/unsensitive	4						
Ability to perform maintenance and change parts while the system is running	5	Visualize redirection and independency of flow in chart		Independent		Fulfilled	10
The system can run with parts of the system stopped due to failing components	5	visualize on flow chart		Independent		Fulfilled	11
The system is easy to install	4						
Fit current factories footprint	5	Visualize merge drawings	-			Needs further investigation	12
Quick installation	2	Time to install	day	< 5	< 14	Needs further investigation	13
Not stopping the manufacturing during installation	5	Time the pray drying process is stopped	s	0	Further investigation	Needs further investigation	14
Easy to lift and handle	2	Fit standard lifting equipment	Yes/no			Needs further investigation	15
The system can be implemented and adopted to different customer needs	4						
Fit a variation of customer needs	4	Fit multiple flows	m ³ /h	15 000 - 250 000	200 000 - 250 000	Fulfilled	16
Ability to make changes with low effort	4	R&D- man hours	h	0	Further investigation	Needs further investigation	17
Ability to easily be adapted to different flowrates (Modular)	4	Components possible to use for other system sizes	%	80	20	Fulfilled	18
Ability to use the same components for the other Segments (Modular)	4	Components possible to use in other segments	%	80	10	Fulfilled	19
Have extra space in confined spaces in case of additional installations of parts.	1	Subjective				Fulfilled	20
Drupps system never affects the spray drying process							
Stops required during installation	5	Time the spray dryer is stopped due to Drupps system	h	0	Further investigation	Needs further investigation	21
Stops required During maintenance	5	Time the spray dryer is stopped due to Drupps system	h	0	Further investigation	Fulfilled	22
No changes to the quality of the inlet air	5	Particles per volume	ppm	0	Further investigation	Needs further investigation	23
Easy to produce							
Few different specially designed components	3	Number of designed components	Number	< 10	< 20	Fulfilled	24
Reuse parts and components in the system with variation in flow rates	3	Number of similar components	%	100	50	Fulfilled	25
Use the technology and components that are used in the other verticals	1	Number of components	%	> 80	> 20	Fulfilled	26
Easy testing at (manufacturer hired by Drupps) before shipping							
Ability to assemble the majority of components at manufacturer (manufacturer hired by Drupps).	3	Parts assembled at manufacturer vs. at customer	Number	> 80	>20	Needs further investigation	27
Simple assembly	3	Subjective				Needs further investigation	28
Easy to ship							
Fast delivery	3	Fit Standard container size measurements	Use standard	20, 40 foot, high cube		Fulfilled	29
Low cost for transportation	4	Fit Standard container size measurements	Use standard	20, 40 foot, high cube		Fulfilled	30
Easy to load when shipped	3	Extra space/wiggle room for components	mm	>200	>100	Fulfilled	31
Easy visualization during sales presentation							
Displaying the main core components to customers in the sale process	1	Visual components	%	100	20	Fulfilled	32
Easy to visualize the scalability of the system to new customers in the sale process	4	Subjective				Needs further investigation	33
Easy to determine cost	1	Time to calculate	min	< 4 min	< 7 min	Fulfilled	34
The system is a good investment							
Low payback time	5	Calculate payback time	Years	2	4	Needs further investigation	35
Optimization In size based on the Evaporators capacity.	3	Deviation of flow capacity vs. evaporator capacity.				Needs further investigation	36
Distance between pad and fans	4	Distance	mm	>350 (longer is better)	150	Fulfilled	37

1. Safety guardrails will need to be added to the outer side of the main frame to prevent operators from falling, which could be achieved with a simple design, such as adding two horizontal bars to the outside of the frame.
2. The electrical switches were outside the scope of the thesis, but there is nothing in the current design that would prevent their installation.
3. The length is greater than 1500mm.
4. According to the technicians, "it looks like it would be easy," but to be certain, a functional model could be built and tested for verification.
5. Due to the system's ability to be shut down in sections for servicing, this need is considered fulfilled at this stage of product development, but testing is recommended to confirm.

6. Technicians noted, "it looks like it would be easy," but a functional model could be built and tested to confirm.
7. There is sufficient space to disassemble and remove the largest parts from the installation, which could be verified on a functional model.
8. This aspect is subjective and would need to be verified with a full-scale physical prototype.
9. Components are independently accessible.
10. The system can be shut down one minimal unit at a time, allowing the rest of the system to continue operating without needing a full shutdown. This need is considered fulfilled at this development stage, though testing is recommended to verify.
11. With the ability to shut down one minimal unit at a time, the system can continue operating even if a critical component fails. This need is considered fulfilled at this stage of development, but testing is recommended for confirmation.
12. The exact installation space available at specific customer sites is unknown. However, the modular design, configuration flexibility, and ability to stack units increase the likelihood of successful installation. Fulfillment of this need must be assessed on a case-by-case basis.
13. This should be tested on a full-scale model, though testing individual sections initially could provide useful insights.
14. The distance between the Drupps installation and spray dryer may vary and would require further investigation to validate.
15. The design was intentionally developed to facilitate handling, but testing would be required for validation.
16. The modular design allows for customization to meet customer needs.
17. This will depend on the changes required.
18. The modular design supports adaptation to different flow rates.
19. The modular design enables the use of the same components across all business segments.
20. Currently, the available extra space is considered sufficient to mitigate risks of design changes due to tight spaces.
21. This would need to be reviewed with each specific customer.
22. With the ability to shut down one minimal unit at a time, the rest of the system can continue operating without the need for a full shutdown. This need is considered fulfilled at this development stage, but testing is recommended to confirm.
23. This should be tested and discussed with each specific customer.
24. Ten parts are custom-designed.
25. Based on the HEAT installation, 100% of the components are used in other systems.
26. Based on the HEAT installation, 100% of the components are used in other systems. The heat exchanger is an external product and is therefore not included.
27. This will need to be reviewed with the manufacturer.
28. This will need to be tested.
29. The system fits inside a standard high-cube container.
30. The system fits inside a standard high-cube container.
31. The dimensions are fulfilled. Testing with a prototype is recommended to determine ease of loading and unloading.
32. All critical components can be shown in a single system image.
33. This could be tested by presenting variations to different customers and gathering feedback on their experience. Pre-prepared images, as shown in this report, could be used to illustrate the different configurations.

34. By dividing the customer's flow volume by the capacity of one unit (based on customer specifications), the number of required units can be determined. The cost per unit can then be multiplied by the number of units needed, allowing for these calculations to be completed in under four minutes.
35. This requires an assessment of cost savings for the customer and must be evaluated individually.
36. This depends on the evaporator capacity, as there are different models.
37. The distance is 1600mm.

5.6.3.1 Safe to operate

The need “Safe working on heights” and “Technicians can by themselves secure personal safety when handled dangerous machines” are not fulfilled at this point. What would be needed to be added to the design is a stairway for emergency in case of fire or other accident, as well as safety protection for walking and the heights, such as railing along the sides of the main frames with the function as platform for walking on. The need to secure personal health was related to the fans and would be handled with a manual switch during the detailed engineering.

5.6.3.2 Easy to service

During service one minimal unit is service at a time, the airflow is cut for that specific series of chunks to allow a peaceful environment without having to rush. The other unit will still be in full production. The needs for “Easy to clean Heat exchangers”, “Easy to change filter” and “Plenty of time to perform service”, relates to space within the main modules and the space requirement where fulfilled and feedback from technician, “looks like there is plenty of room” indicates the criteria is fulfilled, based on the CAD design only. The time to perform service is solved by having redundancy in the system by allowing each duct to be closed independently. This gives the opportunity to shut down the fans and pumps dedicated to that particular minimal unit, which lets the system continue to operate, while the service is performed without rushing. This works only for systems with more than one minimal unit, for example, the target capacity was 300 000 m³/hour, and contained twelve minimal units, changing of filter and cleaning one heat exchanger at a time, that would mean the system runs at $11/12 = 91.7\%$ capacity during service. By programming the fans to increase the speed for the other fans or add one more minimal unit the system could be operating constantly at 100%. The system therefore never affects the spray drying process, which is one of the most important needs. “Easy access to perform service” would need access to the upper floors and the structure and is not fulfilled yet, but by adding a stair the criteria would be fulfilled. “Easy handling of bulky spare parts” is facilitated by the large space provided by the main frame platform allowing physical access to the chunks. The components are reachable independently with fulfillment that need.

5.6.3.3 The operation is robust

As described in the previous chapter “Easy to service”, the need “Ability to perform maintenance and change parts while the system is running.” Would be fully fulfilled as a part of the system can be stopped, having low impact on the overall capacity. With that in mind the need “System can run with parts of the system stopped due to failing components” is fulfilled since there is redundancy for all components for the products designed within the scope. Affects for parts of the system outside the scope will not be covered here.

5.6.3.4 The system is easy to install

If the system will fit the current factories footprint is hard to tell, because each company has different conditions and space limitations. Although, by having a modular system, the system

can be arranged in various ways to improve the chance of fitting any location. The modularity also gives the advantage of scalability, which would allow the spray dryer users to capture for example half of the flow of residuals. The relatively small modules with designated holes for forklifts and hoists at the top to connect lifting straps, facilitates lifting and handle the parts during installation.

Regarding installation time, as the article for preassembled houses suggests, it may be an advantage to have the main modal preassembled and ready to connect. Although this is hard to determine at this point of development.

By installing the large duct last in the installation, the spray dryer would not have to be stopped as the flow can be let out as usual before connecting the Drupps system.

5.6.3.5 The system can be adopted to customer needs

The modular architecture allows for the system to fit a variation of customer needs and allows to make changes with low effort. The extra space in the main frame allows additional parts to be installed if needed. Although this comes at the cost of a larger footprint for the product.

5.6.3.6 The system is easy to produce.

The system design has specially designed parts that needs to be developed further and a deeper analysis of design for manufacturing as well as to be tested. Although many parts are specially designed, they are reused in many of the system configurations. The same parts and components are used in the system regardless of flow rates and business segments. The testing is made easy by having the critical parts tested while mounted in the main frame as they are being shipped in. The assembly would be considered relatively simple and not a reason to hinder it to be outsourced by any manufacturer.

5.6.3.7 The system is easy to ship.

The dimensions of the main frame were chosen to fit two main frames into a standard container which was the criteria for fast delivery, low cost for transportation and the dimension allows the main frames to be easily loaded when shipped. The space needed to easily fit the main frame would need to be investigated further as it is a tradeoff between easy to load in and out of the container, and space to install the absorber. A physical prototype that could be loaded into the container as well as to be fitted with an absorber would be needed to determine if it would be possible to use the current measurement.

5.6.3.8 Easy to visualize during sales process.

The system would be considered easy to be visualized and demonstrated during sales presentations due to the repetition of similar units. By first explaining the minimal system, the core components are explained, and the customer could determine the number of minimal systems needed to cover the full, or part of the full residual flow from the spray dryer. By using the examples presented in this thesis, the scalability of the system could be visualized to new customers. The number of units would be somewhat proportional to the cost, but the installation and piping to integrate the system would have to be determined separately.

5.6.3.9 Other needs

The payback time is impossible to determine at this stage due to the many variables. Analyzing the need "Optimization In size based on the Evaporators capacity", the evaporator capacity is not fully determined and could vary, although the number of absorbers would be the component determining the optimal size based on the evaporator, the current modular design allows any

number of absorbers and therefore the size could easily be adjusted by adding or removing one minimal system i.e. one absorber at the time until the optimal size is found. The distance between the pad and fans were measured and fulfilled by the ideal value.

6 Future development

This chapter presents feedback on the design from Drupps employees as well as further development, testing and evaluation if the design is pursued for further development.

6.1 Feedback on the design

The design was shown to the Drupps employees and feedback was given. The following feedback and questions on further design was given:

- Sending only two main frames and floors as platforms in the container is not ideal way of using the container space.
- How would the main frame be dimensioned to hold the load, and variety of loads?
- How could the loading and unloading be tested?
- How could the assembly be tested?
- What is the cost per square area compared to a basic mezzanine and placing the component on top of that?
- How would the structure be light-proofed? Does it matter if it is painted or in stainless steel, and how would it be possible to ground the structure, considering the “fasteners”?

6.2 Further development needs

List of future development needs:

- Main frame
- Safety guardrails
- Accessing all floors
- Integration of buffer tanks, pumps and evaporator to the installation

Main frame

Much of the feedback regards the development of the main frame. The main frame is a central component of the concept and if the design should be further developed, a more in-depth development of the main frame would be suitable. The same product development process in the thesis could be used with focus only on the main frame, i.e. exploring a large solution space and eliminating inferior solutions and solution combination by decision tools. New evaluation matrixes would be used based on criteria specific for the development of the new main frame. The criteria would have to be investigated further but could include use of material, mass, assembly time and cost.

Further development for the parameters; maximizing cargo space as well as the strength of the structure, while minimizing the cost could be done by evaluating alternatives such as:

- Different models of main frames, with varying thickness on the beams, depending on the placement in the system and how many are stacked on top.
- Using one standard reinforced main frame that could be placed on all levels, being dimensioned by a predefined number of main frames stacked on top of each other.
- Using one standard lighter main frame and reinforcing it with a variation of thicker walls to carry the increased load the more stories the system requires.
- Modular main frames. Main frames are based on predefined beams with modular connections that allow for changes in the main frame, both to make it bigger and also

smaller. It would also save space and fit more of the platform main frames in the cargo container, which could be sent unassembled and mounted on site.

- Investigate if the main frames could be attached directly with bolts onto each other without the “Fasteners”.

Safety guardrails

Safety guardrails would be needed because they are essential to prevent falls and protect operators when working on the installation. Testing is crucial to ensure that the guardrails meet safety standards, withstand necessary loads, and remain durable under operational conditions. From a design perspective, guardrails should be easy to install and maintain, with consideration for durability in potentially corrosive or high-stress environments. This could potential also help carry load, this would have to be further explored. They must not obstruct access to system components or hinder operators from removing spare parts.

Accessing all floors

Function accessing all floors, for example stairs, the design would have to be evaluated separately. Safe access to all levels of the installation needs to be provided, ensuring operators can reach all levels securely. Detailed engineering could include sturdy handrails, non-slip surfaces, and compliance with relevant safety standards to prevent accidents. The design of the stairs should align with the previous requirements, for example integration without increasing the installation’s overall footprint or shipping logistics as the fit in a standard container.

Integration of buffer tanks, pumps and evaporator to the installation

Integration of buffer tanks, pumps, and the evaporator into the installation is needed, and a separate concept development for this may be required. Potential solutions could include using an empty main frame to house the equipment, keeping the standardized structure. Other alternatives might involve adding a mezzanine with a solid foundation to place the installation on top, with the components housed below, or simply positioning the remaining components separately in accordance with the customer's site layout where space is available.

6.2.1 Testing

Structural load

To determine if the main frame, with or without the walls, can hold the applied forces of weather, lifting and stacking the modules on top on another a FEA could be made. The beams can be dimensioned based on the number of modules stacked, which depends on the currently unknown, available area at the manufacturer. If the construction becomes too heavy, decision must be made whether to make several main frames that can take different loads, to reduce the weight, with the downside of losing standardization, or if alternative solutions such as reinforcing the walls of the lower modules. To design the reinforced walls, topological optimization would be used to optimize the weight to possible load ratio.

loading and unloading the main frame

To determine how easy loading the assembly chunks in and out of the cargo container, while keeping the maximal height inside the main frame a first prototype made of a wood frame could be tested. The dimensions could easily be iterated to find a good compromise before making the first prototype with the final dimensions.

Assembling and economics.

The first prototype could then be assembled as three different units with corresponding parts. After iterating the design, another main frame could be ordered and assembled onto each other in all directions to evaluate the concept of attaching the main frames onto each other.

With three main frames and the necessary components forming a prototype of the minimal system, the ergonomics, serviceability, and function could be tested before scaling up the system. The design allows for making tests on the prototype early before moving on with further development, which requires smaller investments and facilitates changes to be made at low cost during development.

6.3 Further evaluation.

The conceptual design presented should be seen as a first iteration of a new potential platform concept, that could be further developed if the concept is considered competitive among other alternatives such as a standard mezzanine to place Drupps equipment on. A comparison performed with the help of a scoring matrix could help determine how competitive the solution suggested in the thesis holds up against the more basic mezzanine. And if the possibly higher cost associated with the benefits of facilitated testing, product variation, keeping stock, postponement, installation would outweigh the lower cost associated with a simpler design. But before a comparison is possible, some further development must be made. The amount of development needed to make a fair and realistic comparison is hard to predict beforehand, but some first steps of further development presented in this chapter may be sufficient.

Reason for the design to be successful

The product's adaptability to customer needs without requiring design changes is crucial for multiple stakeholders. As a startup with a small team and a capital-intensive product, the company must allocate resources carefully. The modular design streamlines the development process, enabling the mechanical designer to focus on a limited set of components that can serve various customer requirements. As mentioned earlier, this approach not only simplifies the logistics and inventory management but also maximizes resource efficiency by minimizing part variation and enhancing flexibility for different customer applications. To recap, some of the stakeholder needs the design addresses, and therefore increases the chances of success, are: *assembly of the majority of components before shipping, facilitating factory acceptance testing to assure quality, easy shipping in standard cargo containers, relatively small chunks to lift during assembly at the customer site, few parts to install at the customer site, modularity with interfaces to facilitate adding new chunks and adapting to variations and new needs, few specific components, and reduced R&D hours.*

Risks to not be successful

If the design fails to meet specific customer requirements and many customers require custom, engineered-to-order installations, the benefits of standardization will diminish. Consequently, lowering the sales of the developed modular design. The modular design might be more costly to produce in small batches which is particularly challenging for Drupps as a emerging company that might initially sell only a few systems to validate the product and handle installations with existing work force. This limited production volume could result in high manufacturing costs, posing a risk. Additionally, customers may feel hesitant to invest in new

technology, and the higher initial production costs of the modular design may further impact early sales.

Customer feedback

There are many parameters to consider in determining whether the design will be successful. Customer needs may vary across geographical regions, as well as within specific markets and applications where Drupps technology will be implemented. Customers may value design features differently based on these needs and unique requirements. Given the wide range of industries and the global reach of potential customers, the ranking of key criteria may differ significantly. Since the number of interviewees was relatively small, a useful way to assess the design's suitability is to present it during customer meetings and gather feedback. While this feedback may not always be consistent or entirely accurate, it can offer valuable insight into which aspects of the design are appealing and where there is the most potential for improvement, considering both industry and regional differences.

Pros and cons with modularization

The modular design has some potential benefits and challenges, it fits Drupps current uncertainty with product portfolio and has potential to be a satisfactory design in long term. Although the higher price for the first produced system, before lowering the cost by producing parts in bulk, might be a considerable disadvantage before the first sale of a system to get a customer reference. The first system could be engineered to tailor fit the customer's needs.

6.4 Comments about rejected concept.

The "24/7 operation" - Concept "I" was disregarded in the elimination process, although it may be an interesting concept for some specific customers, and perhaps the function of run the Drupps system independently of the customers main process can be applied to the remaining concept without too much design changes. The customer that may be interested in atmospheric water generation from ambient air are the ones obligated to save water or have a local regulation determining a maximum water consumption for the production. If the customer's production has many stops or is not operation 24/7, this can be a good time to recover the water consumption limit or even be net producers of water if the local area has a temperature and humidity allowing it.

7 Discussion

In this chapter, the research questions are answered, challenges and limitations are discussed, and reflections on the process are provided.

7.1 Research questions.

- RQ1 - What are the needs and constraints for companies using the spray drying in their manufacturing process?

The needs found from interviews with different stakeholders, as well as observations at Drupps are listed in Table 10. The stakeholders where, producer of spray dryers, users of spray dryers, project leaders in energy sector, retailers of spray dryer, retailer specializing in heat exchangers, technicians, Drupps employees, CEO, CTO, CSO, COO / Logistics, Sales, Market, R&D.

Table 10, Needs organized into hierarchy

Need organized into hierarchy
Safe to operate
Safe working on heights
Technicians can by themself secure personal safety when handled dangerous machines
Easy to service
Easy to clean Heat exchangers
Easy to change filter
Plenty of time to perform service
Easy access to perform service
Easy handling of bulky spare parts
Perform service comfortably
Components are reachable independently
The operation is robust/unsensitive
Ability to perform maintenance and change parts while the system is running.
The system can run with parts of the system stopped due to failing components
The system is easy to install
Fit current factories footprint
Quick installation
Not stopping the manufacturing during installation
Easy to lift and handle
The system can be implemented and adopted to different customer needs
Fit a variation of customer needs
Ability to make changes with low effort
Ability to easily be adapted to different flowrates (Modular)
Ability to use the same components for the other Segments. (Modular)
Have extra space in confined spaces in case of additional installations of parts.
Drupps system never affects the spray drying process
Stops required during installation

Stops required During maintenance
No changes to the quality of the inlet air
Easy to produce
Few different specially designed components
Reuse parts and components in the system with variation in flow rates
Use the technology and components that are used in the other verticals
Easy testing at (manufacturer hired by Drupps) before shipping
Ability to assemble the majority of components at manufacturer (manufacturer hired by Drupps).
Simple assembly
Easy to ship
Fast delivery
Low cost for transportation
Easy to load when shipped
Easy visualization during sales presentation
Displaying the main core components to customers in the sale process
Easy to visualize the scalability of the system to new customers in the sale process
Easy to determine cost
The system is a good investment
Low payback time
Optimization In size based on the Evaporators capacity.
Distance between pad and fans

- RQ2 - What product architecture can satisfy the needs and constraints of the currently used AWG technology?

There are probably many product architectures that could have satisfied the needs, but by following the chosen development process, and evaluation different alternatives, the modular architecture and clustering shown in figure 7.1 was found to be the best fit for the needs and constraints. Based on the current input from the stakeholders, the modular architecture offers adoption for both variations in flowrate, but also the different needs across business areas. It also has other benefits, such as factory acceptance testing before shipping, scaling of the sales and supply management.

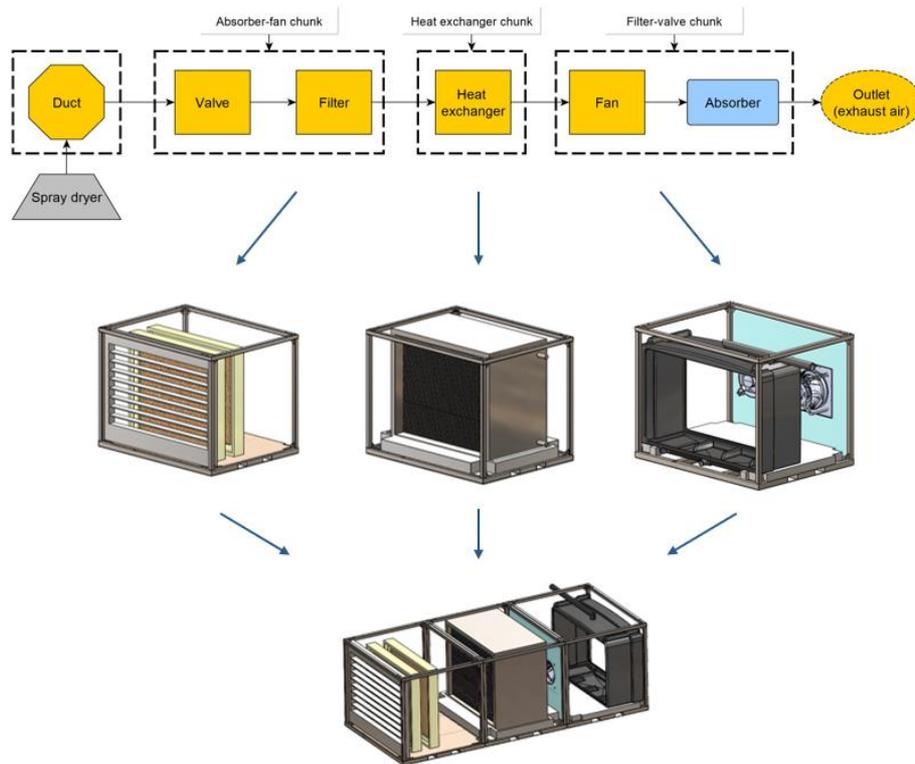


Figure 7.1. Clustering of chunks and assembly of the smallest system with one of each chunk

- RQ3 – How can a concept be designed to meet stakeholder needs and requirements for integrating current AWG technology into existing industrial processes that use spray dryers?

The final design is one example of a design to meet the needs and requirements. The design allows for the product to be adopted to the customers available space for installation, does not affect the spray dryer process and can be tested before shipping.

7.2 Challenges and limitations:

In this section some challenges and limitations that affected the thesis and results will be discussed.

Gather information and feedback on the concept.

To understand the customer needs, more than 40 potential customers, buyers, users, and OEM, original equipment manufacturers were contacted through mail since there was no other contact information to be found. Some replied they were not interested, did not want to share information, or did not have the time, while the majority did not respond at all. The interviews with the potential customers were somewhat informative and needs could be interpreted, they were still cautious about sharing sensitive and precise information. Although a larger sample size of potential customers would be beneficial, the many different perspectives from technicians, Drupps full perspective, observations as well as external project managers in the same industry helped understand the challenges and provided a seemingly clear picture which aligned with the one the potential customer described. The needs converging and for the last interviews no new needs arose, which is positive.

A more rigorous investigation of how the needs were really satisfied.

Due to the lack of answers from the contacted, no feedback from potential customers was received, this would have been beneficial to confirm the direction of the final concept. Ideally, feedback from several customers would have been collected to have a dialog about the concept. From that, hopefully a conclusion about how the needs would differ among the customers could be drawn and perhaps what compromises in design would be possible.

Competitor analysis

In the search for competitors, no company was found with the same technology and application, or other technology with the same purpose for the same type of application.

7.3 Reflection on process:

By utilizing the product development process outlined in the book *“Product Design and Development”* by Karl T. Ulrich and Steven D. Eppinger from 2016, a structured approach was implemented to gather customer needs, generate concepts, and evaluate those concepts. This methodology provided a clear framework, enabling the design process to follow a logical progression with smooth transitions between steps. However, one area for improvement in the concept evaluation phase would have been to follow up the Pugh matrix with a Kesselring matrix with weighted scores for concept scoring. Incorporating weighted scores would have refined the evaluation process, ensuring that the most critical needs were more accurately reflected in the design. Not using Kesselring may have impacted the result of the final design.

8 Conclusions

Summary of results

The final design was based on the enlisted needs of stakeholders; producer of spray dryers, users of spray dryers, project leaders in energy sector, retailers of spray dryer, retailer specializing in heat exchangers, technicians, Drupps employees, CEO, CTO, CSO, COO / Logistics, Sales, Market, R&D.

The design has a modular architecture that designed based on the needs such as safety, serviceability, adaptability, and ease of installation, minimizing disruption to the spray drying process and minimizing downtime. The modularity allows it to be adopted to customer specific flowrates as well as three different targeted industry needs.

The modular design was in line with Drupps product portfolio, and as a emerging company. Although there are both benefits and challenges with the modular design presented in the thesis, the modular design not only have the potential to meets the immediate needs of customers, once the functions are confirmed with testing, but also has the potential to position Drupps as a leader in sustainable water recovery technology. Its adaptability ensures compatibility across diverse industrial processes, providing a versatile solution that can evolve alongside market demands. As the global emphasis on resource efficiency grows, this product has the potential to set a new standard in atmospheric water generation, bridging innovation and practicality to create lasting environmental and economic value. By addressing both current and future challenges, Drupps is paving the way for a more water-secure and sustainable industrial landscape.

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Appendix

Appendix A - Interviews with stakeholders

Retailer specializing in heat exchangers

Behöver lamellerna på värmeväxlare rengöras även om filter används?

- Lamellerna i värmeväxlaren kan absolut behövas göras rent.

Hur ofta behöver de göras rent?

- Om luften som går genom värmeväxlaren är jättesmutsigt kan de behövas göras rent varje vecka eller till och med varje dag. Är det ganska ren miljö och väl filtrerad luft så borde lamellerna tittas till åtminstone en gång om året. Det är lättare att göra rent om det inte går för lång tid mellan städ-intervallen och det blir alltför för smutsigt. Torra partiklar är bättre och fastnar inte lika lätt, det gör att man inte behöver göra rent lika ofta. Kletiga partiklar har benägenhet att fastna.

Har du exempel på värmeväxlare som har behandlar mjölkpulver? mellan tummen och pekfingeret.

- Jag vet bara ett projekt, det var ett mejeri från Norge som hade alla batterier helt i rostfritt. Där ingick rengöring av lamellerna i deras dagliga städrutin som de hade varje dag. Deras lameller var i rostfritt stål bara för att de skulle kunna använda samma rengöringsmedel som de hade i produktionen och använde för att rengöra och sanitära produktions kärlen. Rengöring av deras tilluft ingick i dagliga städrutinen tror jag, även om den inte alls va lika påverkad, på lamellerna i frånluft började det byggas upp smuts nästan direkt. Smutsen gör att värmeöverföringen blir mycket sämre och minska verkningsgraden.

Hur stort utrymme framför värmeväxlaren skulle du säga är bra för att kunna rengöra ordentligt?

- Det är nog 1 till 1,5 m för att kunna gå in och få plats för att kunna komma åt och göra rent. Ofta behövs frånluften göras rent oftare, men det är bra att göra rent växlaren vid tilluften också.

- De Vanliga ånga och högtryckstvätt

Finns det andra metoder för att göra rent?

Om man inte använder rostfritt,

Aluminium - göra rent med högtryckstvätt och kemiska rengöringsmedel. gärna tjockare lameller och ganska gles lamelldelning. djupt batteri.

12 -delat lamelldelning. Dela batteriet i 2

Kolsyre - enzymrengöring. ångrengöring - aluminium och koppar klarar der.

om man vill använda lösningsmedel eller klorin ska inte koppar eller aluminium användas. ytbehandling harrysite för hartsbaserad ytbehandling som batteriet doppas i skorpa.

Superhållbart för livsmedelsindustri.

Den gör man rent genom högtryckstvätt, ånga, klor och det mesta.

Manufacturer (1) of spray dryers

Can you tell me about your role at the company, and responsibilities?

Senior sales managers, working at the company for 25 years. Responsible for sales in Europe but working world wide. Process engineering background.

How many customers do you have?

We deliver 200 machines and 50 plants per year for drying, and have done that for 50 years but about one spray dryer per year, or at least not every month. Although we have fluid bed spray dryers. Much of the knowledge in drying is very similar, so you should not vary too much about one specific area. You wrote about exhaust air, and that is in all drying processes so other processes can be interesting too.

What are the different flow rates?

Not to talk about laboratory equipment, but it starts at about 5000 cubic meters and the bigger ones are up to 50.000.

Could you say something about the variation in needs you have encountered between different industries?

If you collect particles from the exhaust air in the drying process with a filter, for sure it will have to be cleaned. If you have milk products, which are common, then there are special filters. Then CIP cleaning can be used, without opening you can clean without opening and no biological development from the residual material. It is used in food and pharmaceuticals. Also regarding this, you need to avoid sharp corners where food could accumulate and grow, it could also be hard to clean.

If you have heat recovery and dehumidifier, I guess you first need to clean the air.

How do you avoid clogged heat exchangers?

One strategy is to avoid temperatures that cause condensation. And there are existing heat exchangers that have a special water cleaning system. They can be used for potato starch and other starch products.

What do the customers value in the integration of new equipment, like specific features or functionalities?

Regarding the design, generally speaking it is always a question of cleanability, and the main thing for the client is that they want profit, in the end it is about money.

For example if you have a dryer, it does not matter what type of dryer, if you want to change the product, you do not want the old product left. you do not want the wrong substances to start with. If you can avoid losing material in the change and minimize cleaning time, when you change products.

It depends on which country you deliver the machine and dryer to, let's say in countries with lower education it is more important with a more simple and easy to understand design. The best would be to have no maintenance needed, because the operation might not always have so skilled employees.

How do you handle customer constraints?

The main criterion is operation cost, and then the cost for heating. However you do it, this is the main criteria. The physical space is more or less given. Sometimes the customers do not have the space needed for the drying system, it is also a question about money.

If the space is too little we do not have a clear strategy, but then we tell them to consider another place for the installation. We are not so flexible with the installation of the biggest parts of the system, those need the specific space. also we need to take into consideration the ductwork that is connecting the system. But basically you could install all the separate parts more or less wherever you want within the range that the ductwork allows. So as long as you can connect all the parts you are actually flexible. But you need the space somewhere! Even if you can connect them.

The product is developed for low operation cost and optimal heat. So if there is really no space that is a “show stopper”. The drying does not have a one metric constraint, with one height, length, and width. There is a benefit for the layout engineers, and soft criterias for clever design so we can make it fit better.

Sometimes the inlet air and the outlet air differ very much in temperature and that could be difficult to heat exchange.

How do you handle heavy loads on the roof?

It depends on the customer and the system but we sometimes put the equipment on the floor and have ductwork connected to the roof and the exhaust. That is more or less an advantage. It is not a problem to do that. It will not affect the drying process. If it is very long it might need some fans to avoid pressure drops.

Do you have any suggestions how the product could be improved?

For shipping it is a cost question, but it can always be solved.

Cleanability for sure should be taken into consideration.

Also maybe to avoid installing equipment on the roof if that seems to be a problem for the manufacturer.

Good accessibility for service and maintenance. For example to be able to access motors to replace in case there would be some failures.

Interview with a company (1) using Spray Dryers.

- Can you tell me about your role at the company?

I have worked several years at the company and have a background in chemical engineering and work in global research and development. modeling of spray drying and other equipment, product properties and CFD-modeling.

- Have you had ad-ons to your current process and how do you handle the integration of the equipment to your current process?

I am not involved in that process but one year or half a year ago when the energy prices went through the roof we were putting low hanging fruits on the heat integration and adding to the spray drying process.

- Can you tell me more about that installation and integration?

I was not involved in that, I am sorry.

- Can you tell me about what characteristics you value in mechanical products, such as serviceability and maintenance?

It is more of a money question, really! if it pays back, we install it.

- So that is the most important thing for such equipment.

Yes. We buy a whole factory most of the time and it does not happen often, and it is good for 50 years or so.

- Can you tell me how you handle maintenance?

There are a lot of contracts about that, but i can't tell you about that.

- What is your particle size after the cyclone filter?

We have different filter sizes for different productions and it depends on the product. We measure what comes out of the cyclone and it is a size distribution in the end. We are talking about between 1 and 100 microns approximately. but we can still recycle whatever comes out of the cyclone we try to feed back to the spray dryer. and The outlet air of the cyclone still contains some milk dust and the size distribution is 20, 30, 40 microns and that we need to filter out. We catch it using a filter called a backhouse filter, basically a bag. that we can not use, we just get disposed of, no actually we recycle it to cattle-food instead of throwing it.

- Regarding constraints on interfaces at your factory, Do you have drawings of the facilities that show the outlet and inlet air from the spray dryer?

We have 3D- programs for the whole factory, but I am not allowed to provide that, sorry. but that should not stop your project, if you know the flow, you could design your product and if it is really huge, we just put it on the roof. You should not worry too much if there is space in the building.

- Does the position on the vents differ? - Let's say it is on the walls or on the roof?

Let me show you a picture. (Shows picture of a factory) It is a 20/25 meters high building, the main air inlet is on the side of the building and about 20 meters high. The outlet air is on the roof of the building. There is actually a lot of room on the roof, the picture does not display everything, there should be some more room on the top. I mean the more compact the better but there is room.

- Is it always that you build the inlet on the side and the outlet on the roof?

It is different between the facilities.

- Would it be an issue to rearrange the vents in order to install the product on a better spot.

The drying capacity is dependent on how much air we suck through, so we do not want to lose pressure. sense your device causes extra pressure drop. You should see if our fans can handle your pressure drop, if they run at maximum right now.

- We have our own fans that will cover for the pressure loss. So I am thinking more of the physical mechanical constraint of connecting the flows if there is not enough space on the roof for example.

I think that is also a money problem, physically it should be possible as long as the pressure loss is covered. Rearrangement is fine, the outlet is where it is.

- Is there anything else you think is important for the integration?

I think you should focus on the design to bring down cost, that is what will make it possible.

- Could you provide the actual picture, measurement for the facility?

I am not sure I want to give that away, that is more of a legal thing. The smaller the better, I think. The larger it is, the more money it will cost in the end.

Interview with COO at Drupps

Summary of the interview:

En första design baserades på en containers innermått och produkten var designad så den precis gick in i containern, det gjorde att den tog väldigt lång tid att lasta och var väldigt svår att få in i containern. Tid är pengar. Det gjorde också att produkten inte gick att spänna fast eller säkra. så inte ytan i containern.

Kostnaden för att frakta på sjö är den lägsta som vi har och att använda standard containrar är det absolut enklaste och billigaste. gå på det aldra mest standard, så Antingen 20 eller 40 fots containrar. Den kan va high kube men det är svårare att få tag på. det finns öppna containrar och speciallösningar men man vill helst ha det allra mest standard eftersom det också är det lättaste att få tag på. Om man designar något som precis från plats går det att lösa men det är alltid dyrare. Vi vill ha delar som är designade enkla att lasta som vem som helst kan lasta.

Den person som vi anställt och är riktigt duktig på att lasta saker tog det lång tid att lasta. Så vi vill att någon som inte är lika erfaren eller skarp också ska kunna lasta utan att förstöra utrustningen utan att det ska ta för lång tid. Det är väldigt viktigt! Vi vill undvika byrååldseffekten och att delar skadas.

Vår egen lärdom är att komponenter ska kunna gå att spännas fast och säkras i containrarna.

Ett önskemål är att vi använder så samma delar som möjligt och inte kund, case eller projektspecifikt. Om inte alla delar så i alla fall vissa. Det blir lättare att trimma in tillverkarna, minska verktyg, kostnaderna, lägga prognoser på produktion. Det finns massa fördelar med att ha samma typer av delar på de små spray dryers som dom stora. Om inte annat att t.ex. fläkthållare är samma så det går att byta mellan fläktar. Lättare att ha lager och bättre tillgänglighet.

När vi skulle göra en stor ställning till buffertanken kunde vi inte göra den i rostfritt, så vi ville måla den, men det fanns ingen leverantör som kunde måla en så stor ställning. Det finns inte så många som kan måla såna men vi hittade en som kunde göra det. Generaliserade lärdomen är att göra designer som många kan tillverka, det gör att man kan ställa leverantörer mot varandra och pressa priserna. Dessutom är det bra om flera kan göra samma jobb ifall det skulle vara högt tryck på underleverantörerna eller att de skulle gå i konkurs.

Det är lätt att designa saker för produktionen men vi får inte glömma att det ska monteras. Vi har samarbetat med tillverkarna att det ska vara lätt att montera ihop. Där kan vi spara mycket pengar och tid. Det är viktigt att tänka på vilken ordning saker ska monteras och att det är praktiskt möjligt.

Det är många lyft vid transport och containrarna hanteras inte så varsamt.

Vi vill minska arbetet på plats och göra så mycket som möjligt av tillverkningen och monteringen i en ren och säker miljö med utbildad personal och rätt verktyg. Men det blir stora delar. Alternativet är mindre delar och montering på plats.

Vår tänkta leverantör i Bulgarien. Man kan anpassa designen efter vad de bästa leverantörerna kan göra men inte binda upp sig allt för mycket. Men vi vill inte ha skraddarsytt efter endast dem, alltså ändra designen efter vad de har för verktyg.

Vi vill ha leverantörer nära förvar kunna göra snabba iterationer på prototyper.

Om det kommer upp behov hos kunderna som vi inte stött på tidigare.

I en önskvärd så skickar vi inte helt färdiga system till kunden men i början kan det finnas risk att vi kommer behöver göra justeringar i efterhand.

Jag vet inte om du kommer ha specifika verktyg.

Det som kostar mest är ställningar och ändringar. Så om vi kan minska ändringar är det väldigt bra.

Om vi pratar ställtid, så är serier runt 20 det bästa, för där är priset som lägst.
Om vi pratar tillverkning så är en tumregel att producera 1 exemplar dyrt för att det är första.
De första 3 exemplarna är bättre för då har de har testat och mänskliga fel minskar.
Sen från 10 är det bra för maskinerna och kvaliteten ökar. Så det kan vara ett riktmärke

Inom en överskådlig framtid kommer vi inte ha saker på lager. Däremot på vissa komponenter med lång ledtid som PLC, sensorer och fläktar.
Just med fläktar så får dom inte ligga stilla för länge för då
Assemblage to order, då kan vi förbereda komponenter. Däremot blir kokaren alltid specialbeställt och det är den tar alltid 6 till 9 månader.
Om det behövs flera hundra upptagets kommer det ta längst tid och då kan vi behöva
Längre fram kanske vi kommer kunna ha prognoser och då kan det bli aktuellt att börja producera i batcher långt innan leverans.
Om vi har specifika moduler som plockas ihop efter va kunden behöver.

*visar ett excell för vilka komponenter som kommer användas gemensamt för alla system.

Tex. Är det bättre att ha ett överdimensionerat endstep som är alldeles för överdimensionerat eftersom det är relativt billigt. Istället för att utveckla ett nytt som är anpassat efter en viss storlek.
Det tänket att kunna använda samma delar är värdefullt.
Snygga bilder, kunderna förstår inte vad vi säljer. Referenser i storlek, en liten gubbe som visar hur stort systemet är. Som senast nere i Spanien så insåg de som besökte anläggningen att det fanns för lite plats. Vi kunde insett problemet tidigare om både vi och de kunde förstå storleken tidigare.
Vi behöver referens projekt.
Om det är många samma komponenter till olika kundlösningar så ger det mer trovärdighet.
Det finns också begränsningar i vikt på containern.
Vår visningsprototyp vägde under 10 to. Totalt med en extraförstärkt container.
Något vi också måste tänka på är hur sakerna ska förflyttas inne på deras anläggningar.
Något som vi kanske måste tänka på är infrastrukturen och om det finns möjlighet att komma dit med lyftkranar eller liknande. Det kommer vara kundens ansvar men vi vill att systemet kommer fram.
Helst vill vi lägga ifrån oss ansvaret i fabriken. Men det kommer nog bli i hamnen. Alla delar kommer från olika platser i världen.
Kopplat till containrarna, det är bra att lägga saker i containrarna för om vi äger våra containrar så finns risk att fraktbolagen prioriterar bort egenägda containrar och fraktbolagen prioriterar sina egna containrar.

Därför är det bästa är att låna en container, lägga in delar i den och sen ta ut delarna.
Det går att container-klassa och certifiera en hemmabyggd containrar men det är en investering och har samma problematik som att äga containern.
För framtiden vill vi så småningom standardisera för att kunna korta ner ledtider, minska ner kapitalbildning, billigare och mer effektiv produktion, mindre produktflora vilket gör det enklare att göra analyser, enklare att göra uppdateringar på systemet.

Interview with sales manager at Drupps

1. (I have noticed that the primary need for the costumers is the technical aspect and saving money, water and energy, But,) -Have the customer asked for other specific features for the system? (Maybe later in the process, as Godej or similar)

Biggest circle, their primary needs are savings in water, energy, and reduction in carbon dioxide. When the customers are happy with that we go to the next circle, the next most important, which is the budget, they like the concept "will it match my desired payback time?" - which is 2 to 3 years.

Next is the quality and the impact of their main process. customers who are processing food are very picky about the safety in terms of bacteria and how our liquid desiccant is impacting their spray dryer. That dust is going to be recirculated, because they do not want old dust coming back to the main process. Their air has to be super clean and some ask for very specific filtration systems to prevent contamination that can impact their process, but this is primarily with monsters handling products for human consumption.

There are customers asking for maximazins water productions instead of carbon dioxide reduction, tesla are often those with low energy prices. They do not care that we can not take care of all heat energy but they like to take care of the entire airflow and take care of all the water. Then some customers have very picky about a certain about of water in the inlet (that is for the other type on system, the pre drying system)

Some customers are very picky with what they want.

Pr - to look god in the sustainability aspect

Customers also have space constraints that could filter out if they want a system or not.

2. Have you encountered other general concerns in the sales process? (worries about constraints or needs. Or some specific part of the system)

The customers are not willing to invest money in something they can not visualise!

The very technically driven people at the customer end are satisfied with diagrams, Mass energy balances, because they understand all the components. But, there are other roles at the custom end and they need to see what they are actually buying and paying for!

They want to know how big this system is. how much does it weigh, and how many of each component will I need.

They also want to know if it does not fit their current facilities, if we at Drupps will adopt the system and fit it to them or do they have to make space for us.

Another huge concern is the piping, they know it will increase the cost a lot and will not be covered in the initial investment, and therefore it might decide if the system will be worth the cost.

The piping depends so much on the design of their facilities, location of inlet, outlet, size of airflow.

One box size that fits it all, all airflows, would be great, because then I can just tell them how much space they need.

The customers are also worried if they need to build separate structures when integrating our system to their spray dryers.

They are afraid to make long ventilation ducts and long piping with lots of isolation.

Piping, vent and structure depends on our design, but we will not cover the cost - that worries the customers.

- Are the customers worried about the cost of the execution and if it is possible?

They will take all the costs. It is always a question about cost, transport, installation.

When we give a price it is for our system, but the actual cost for them is much higher, because of transport, integration, installation and all of that. So they have to take all cost in to consideration (Make it easy for the customer to evaluate the total cost)

I would like to know exactly what I need from them to make a standard in terms of piping, cablems, electricity and give a descriptive list.

like buying an apartment, you know the basic parameters and can decide if it fits your needs and costs.

They like to know more about maintenance, and spare parts, at least for the European customers. How do they get new pumps, filter, cleaning step, carbon, new absium. They want easy supply to maintain the system and easy operation.

So it is in both parties interest to have the easy maintenance and daily operation.

- when you say you want one size fits all, would it be equally sufficient if you, in a simple way, could calculate the needed size of our system based on their parameters, in order to tell them the physical footprint?

Definitely! What I want is an easy way to show the size of it! important is that it is just not one big thing and the price is too high for the small ones because then they won't buy.

We want to reach out to many customers.

Stay alert about the particles, customers have a huge list of questions regarding filters so that has to be taken into consideration.

I would like clear instructions about the filtering system, what our limitations are. What I would like is to identify early in the sales process to identify what we can not do for the customers so we do not waste time. so knowing the limit of the system.

They might be interested in the outlet air when they have contaminated air. That can be for example when handling animal food. There can be toxic gases in the outlet air.

3. Is there anything regarding the mechanical design that could facilitate the sales process?

Maintenance - how often, tydliga instruktioner för bra funktion.

It would be very helpful to know the bare minimum time and effort to keep our system operation and running.

Customers also ask a lot for a system that can be shut on and off, because the operating hours differ from all the customers. Some customers even only use the spray dryers in certain seasons. They therefore often have concern that our process is a continuous operation they won't be able to stop if they want.

An easy and fast start and stop would be very appreciated.

They want to know how much time and money it costs to run our system and what different qualities of filters we can provide, and how that affects the air quality and how often filter change is needed.

4. Even though the customers do not ask about mechanical design right now, do you predict something that might be helpful or facilitate in the future? Example when Drupps have made ex. 5- 10 sales.

5. Are there any features regarding the design that could help to achieve a successful sales pitch or demonstration of the product?

Simulations are super useful, like i chemistry when the school shows you how the air moves and changes into somethings else. It would be like science for dummies.

Make it shippable! take consideration of container size and how heavy it can be. It is very important to be able to get the system to the location where it is going to be installed.

Overview of the system with process flow, the customer wants to know what type of heat recovery it is. if it is reluctant heat and sensible heat different and how they can reuse it in the main process. And how big the value is.

I think it is a problem that the customers are very picky with their needs. and those differ a lot. At the same time they want to see a concept when we do a sales pitch or a presentation and it is difficult to get both.

If we can add and mix and show the specific parts we are interested in.

Also - the customers actually love the modularisation with smaller parts! Because they do not have to adapt to anything. One of their biggest fears is that we will interfere with their main process.

let's say we can handle a very specific airflow, but they need more or less, if we can not adapt, that means they have to, and that is something that is impossible for them to do. We need a solution that fits them all in terms of sizing and temperature, so that whatever they are doing and for however long they are doing it. (intervals, seasons.)

Their process needs to be exactly as it is right now! Nothing can ever change in their process.

- How about taking care of a part of their flow?

A system that does not care for the whole airflow would not be economically viable for the customers. The customer's first concern is cost.

They might be interested in a smaller system but the whole cost has to be taken into consideration. They usually go big or do nothing at all because there are so many costs around the project, piping, duct, contracts etc. that it does not make sense to not do it as big as possible. They will do all or nothing.

What would be very useful for Drupps is a small shippable unit that does not have to be big at all but giving a little bit of water and energy savings.

Try to focus on making one unit that could handle a wide range of flows, big and small, instead of handling many types of contaminations in the air.

They want to know the lifecycle of the product, how long they can use the system for. That is for serviceability.

Interview with two senior project leaders in the energy industry

- **Kan ni berätta om ert senaste projektet och vad har gått bra**

Hur ser det ut med hur mycket de vill skala upp projektet?

Något som ofta används är moduler som byggs ihop med varandra. Det är bra om det går att bygga ut systemet i efterhand.

Försök att få in modul bitar på EU - pallar. Och försök att om det är möjligt att hålla sig inom standardmått som bredden på dörrkarmarna.

Det de har erfarenhet av är att minska yttre anslutningar mellan enheter ifall det skulle behöva vara moduler.

För underhållsperspektiv kan det vara bra att tänka på att kunna nå åt moduler som ligger långt in, eller i gränssnittet mellan gränssnittet.

Beroende på hur tunga de är kan också lyftbalkar behövs.

Komma runt och nå.

Skala upp Modulerna, ifall det behövs.

För mig låter det här likt en rökgaskondensering, som vi känner till i vår bransch. Då kommer säljare och erbjuder mervärde genom att spara mer pengar, med det viktiga är att aldrig störa huvudprocessen. Eftersom det är en plustjänst så är det viktigt att absolut aldrig påverka deras huvudsakliga process.

Det är viktigt att ert system aldrig stör det de faktiskt tjänar pengar på.

Det är svårt att veta exakta regler för varje land men det kan skilja mellan länderna och det är bra att vara förberett på olika lagar och regler men också olika industrier.

På tak är det svårt att montera eftersom det finns risk att det vibrerar, skadar taket och håller tätt från vattenskador. Det är inte säkert att taket är dimensionerat för att kunna klara den ökade lasten heller. Om det är efterkonstruktion kan det bli problem, men om det är nybygge kan det såklart dimensioneras för att hålla.

Vi har behövt montera saker på tak använder vi ANA.

Hur gör de som säljer kylmedium kylare och kylmaksiner. - De vibrerar, är tunga och har vätska.

Om det går att få upp dem med hiss är det bra, annars blir det lyftkranar och i värsta fall helikopter men då blir det väldigt dyrt.

Om systemet ska installeras där det är extremt varmt eller där det finns frostrisk behövs det skydd för det. Du kan också behöva skydda systemet från sand och andra väderlekar så det inte påverkar systemet.

Om ditt eller deras system strular så vill de kunna stänga av erat och sen starta det igen om två dagar och då får ert system inte sönderfruset, uppbränt, sintrat eller dammat ihop så det inte startar.

Om du har mycket damm så kan du behöva redundanta filter så du kan byta det ena utan att stanna ert system. Om dammet bara blåser ut det i luften så borde det inte vara ett problem.

Det låter som varje kund kommer ha väldigt specifika och olika behov.

Om vi ska prata frakt och moduler så gäller det att få plats och lasta i en standardcontainer. Allting blir dessutom mycket lättare att bygga ihop och billigare att bygga ihop och montera i en fabrik än att göra det på plats. Allt ska gärna vara helt färdigt från fabriken och när det väl är på plats och ska installeras är det bara en slangklämma som behövs sättas dit. Arbete och installation på plats är dyrt, att standardisera och ha enkla gränssnitt från fabrik är mycket bättre. Lätt frakt, standardcontainer och EU-pallar är hållhakar.

Jag vet inte om det är bra men transformatorer byggs i containrar.

Stör inte huvudprocessen. De ska inte behöva oroa sig om ert system fungerar eller inte. Det ska vara självgående.

Lönsamt, (skämt)

Min erfarenhet säger att det är fördel om det går att fördela, eller dela upp systemet med delar som inte är beroende av varandra för att spara plats och få plats med mer på trånga utrymmen.

Project manager in energy industry

Kan du berätta om vad du tycker gör ett lyckat projekt?

Kommunikation är A och O, Det gäller att instruktioner är supertydliga och vad som förväntas av alla parter och att alla vet vad systemet gör hur det fungerar och vilka förutsättningar som behövs för att det ska fungera bra. Också hur det ska installeras och kopplas in. Vem som står för vilka kostnader. Också krav för tak till exempel.

När vi installerat solceller var takets bärighet en stor fråga. Det gäller att tänka igenom takets tekniska livslängd om det är värt att göra en investering. Taket kanske har 40 års livslängd - men om de redan är gammalt.

Tydlig gränsdragning! är viktigt när vi ska koppla ihop utrustningarna. När det kommer till koppling med el och liknande.

Vilka kriterier kollar ni på när ni köper nya maskiner?

Vi hade en lång upphandling med massa krav. Men när den var installerad missade vi det stora målet. Och maskinen kunde inte utföra den uppgift den var köpt för att utföra. Det är lätt att ställa massa krav och missar det viktiga.

Tydliga enkla krav. Viktigast är att ha rätt krav

Det tre viktigaste sakerna tycker jag är:

- Funktion - Utföra rätt sak och ge värde.
- Driftsäkerhet, strul krångla.

Hur man ska hantera om det går fel: Utgå för att alla har gjort sitt bästa, ta 100% ansvar och ta 100% ansvar och hur ska vi lösa det. Inte skylla på någon leverantör, alla vet att det inte blev en bra positiv kommunikationsstil.

- service, när den går åt skogen , snabbt, hitta snabba leverantörer.

Tydlig gränsdragning om vem som ansvarar för vilken del av systemet.

Designa för enkel frakt och utforska olika alternativ, för oss blev det billigare att lyfta upp solceller med helikopter eftersom det gick så mycket snabbare.

Interview with marketing at Drupps

Vad efterfrågar kunderna, utöver det tekniska? Som spara energi, vatten, pengar, är det annat också?

Vi vill ha ett varumärke som uppmuntrar till att säga återvinning. Producenter med spray dryers kan använda oss till att spara energi och deras konsumenter som bryr sig om att köpa hållbara produkter kommer i sin tur välja de som anstränger sig för att ha en hållbar produktion.

Vi vill vara kundorienterade och fokusera på hållbarhet. Just nu är b2b inte lika intresserade av ESG frågor och bryr sig mest om pengar och investerare. Det skiljer sig dock mellan olika industrier.

Vi fokuserar på mjukare värden, mindre fotavtryck.

- Frågar kunderna hur miljövänliga vi är?

De kan komma att kolla upp våra leveranskedjor så det gäller att vi är miljövänliga och följer EUs direktiv. Vi kan också komma att behöva undersöka var våra underleverantörer har sin produktion och hålla koll på förutsättningar.

Interview with CEO at Drupps

Intervju för att göra en design som passar företagets strategi.

- vad tyckte du gjorde en produkt framgångsrik hos ditt tidigare företag?

Uppfyller kundbehov bättre än konkurrenterna eller billigare. Vi jobbade mycket med användarvänlighet eftersom det var avancerad teknik och det blev väldigt mycket expertkunskap. Närmast akademiskt. De produkter som tog ett helhetsgrepp kring kundbehoven och formade en arbetsprocess kring produkten var viktigare än prissättningen. Sen kunde vi designa den så den blev billigare eller så det blir lyxigare och passade ett visst segment. Men det viktigaste var kombinationen av funktionalitet och användarvänlighet.

Exempel på arbetsprocessen är hur marknader sökte av områden och fick data och så gjorde kunderna analyser på datan, men det som kunde hända ibland va att du hade fått dålig data som inte kunde användas, det vi gjorde då va att få en snabb uppstartsprocess och kunna avgöra om datan va bra redan ute på fält och se om det va möjligt att dra slutsatser drierk när datan va samlad. på så sätt kunde kunderna spara massa tid och pengar genom att göra geologerna och geofysikerna så effektiva som möjligt.

Just att få resultat och bekräftelse på att systemet fungerar är något som Drupps skulle kunna använda. Det kan appliceras på drift och se att det är bra värden på återvinning.

Användarvänligheten här är att få kunderna att förstå systemet, hantera, starta upp och förstå hur det går i termer av återvinning. Både alarm och stopp, men även i säljprocessen.

Arbetsprocess. -

- Komma igång snabbt
- Enkel Att använda
- Se live feedback hur det går för att få bra resultat och spara tid.
- Alarm och stopp.

prissättning

Vad tycker du är viktigt hos produkten på **kort sikt**? - Hur kan designen hjälpa det?

Standardisering är viktig av flera skäl, Repeterbarheten är viktig för att spara resurser från RnD men också i tillverkning. Så vi behöver inte behöva göra nytt varje gång. Det är viktigt att vi också gör det tillräckligt brett och inte bara en anpassad speciallösning till en viss kund.

Den andra aspekten som är viktigt för oss är att kunna visa kvalitet och performance. Vi ska kunna visa bra, stabila resultat under flera test och hålla den kvaliteten vi lovar utan för mycket underhåll och inte bara visa bra resultat vid ett specifikt test under perfekta förutsättningar - kunna förfina och utveckla med samma gränssnitt.

Eftersom det inte är en beprövad process kommer kunderna vara oroliga över vad som kommer hända om 3 år eller om 5 år om vi byter våra processparametrar om systemet kommer fungera då med. Även om de fortfarande kommer kunna använda vårt system om de byter arbetsprocess eller gör justeringar i deras process.

Och kanske ännu viktigare i närtid, om vår lösning skulle påverka uptime på deras primärprocess, då är det väldigt dåliga nyheter.

Få ner kostnader med standardisering och RnD tid.

Genom att kunderna använder samma komponenter i olika storlekar och typer av lösningar ger det förtroende.

Vi vill ha robusthet i koncept, både producerbarhet och kostnad, montering, kvalitet och installation. Lättare att ge instruktioner i hur montering ska ske, hur lång tid det tar och vet hur det ska göra montering på bästa sätt för vi gjort det på tidigare anläggningar, eftersom du har gjort det flera gånger tidigare.

Om vi har ett distanserat mekaniskt gränssnitt kan vi ändra och byta ut våra komponenter om det skulle behövas eller om det utvecklats mycket. Men även ha möjlighet att ändra vårt system ifall deras process ändras.

- Hur ställer vi oss till extrema behov hos kunderna?

Vi har nu fokuserat på alla kunder som har varit intresserade, men eftersom vi bara är 10 personer så ska vi sluta springa efter kunder som ligger utanför vår core frame. För vi vill inte att de börjar konkurrera med de som ligger innanför ramarna på det vi lättare klarar av. Nu ska vi pausa och göra det senare.

Vi vill designa för de "enkla" kunderna inom ramarna utan att kompromissa för mycket nu, men gärna göra en design som tillåter oss att komma tillbaka till de svårare kunderna senare utan att behöva göra om allt för mycket.

Det ena är en storleksfråga, men om vi ska kunna anpassa till kunder med extrema temperaturer så kommer vi behöva anpassa upptagna, fläktar och veta hur absiumet beter sig. Så vi vill samtidigt ha en enkel design nu till att börja med utan att lägga för mycket tid och energi på att anpassa till de extrema förhållandena. Den första designen får gärna vara enkel.

- Låt säga att vi har fått ett sälj, och du får chans att välja; antingen en lösning som var billig och passade kunden men du kommer inte kunna återanvända så mycket från designen igen. Eller att ta längre tid och kosta mer, men med fördel att kunna återanvända design.

Det är en delikat fråga men jag tror vi vill skapa så mycket standardisering som möjligt, men motpolen är hur mycket kunden vill betala och hur länge de är villiga att vänta.

En del av utvecklingskostnaderna kan dock läggas internt på RnD. Många kunder har lång framförhållning och pratar om investeringar 2025 och kan göra investeringar i samband med ombyggnation.

..Andra utmaningar hos produkten? (Också kopplade till Drupps)

införsäljning av Capex- projekt är långa och har många inblandade, komiteer, utskott och budgetar, som ska vara med att bestämma, det är processen att godkänna. Så även om vi hade varit ett stort etablerat företag så skulle vi ha mycket förhandlingar fram och tillbaka. Så vi måste ha uthållighet och hålla ut i de här processerna.

Det andra är att vi blir subscale i det tekniska säljandet. Det kommer påverka införsäljningsprocessen.

Så det finns risk för resursbrist. Så frågan är hur vi kan skapa verktyg för att tackla problemen. Den primära utmaningen nu är att vi inte har någon installation ute. Då hamnar vi i att vi måste visa oss lite mer än alla andra. Så det är viktigt att vi får till en försäljning för att kunna visa att systemet

fungerar både för kommande kunder men också för de andra vertikaler även om det inte är exakt samma komponenter.

Om vi kan säga att vi använder mer eller mindre samma komponenter, eller åtminstone samma koncept. Att vi använder 12 eller 20 upptagare och om det är exakt samma värmeväxlare eller inte är kanske inte lika viktigt, men just att vi har ett proof of concept och har en lösning som fungerar så att våra första kunder kan lämna oss som referenser att det fungerar.

- Finns det något sätt mekaniska designen kan hjälpa i säljprocessen?

Om vi kan visualisera med en CAD ritning med exempelbilder hur olika installationer kan se ut med respektive huvudkomponenter och tekniska specifikationer på dem för att förklara hur systemet fungerar. Kunna visa upptagare, fläktar med vikt, och hur stora de är. De skulle vara ett bra komplement till simuleringar och Cogs modeller, det skulle vara en grov uppskattning på ungefär hur många vi behöver av varje komponent utifrån deras storlek på fabrik. Det ger en först uppskattning på pris även om det inte tar hänsyn till deras exakta behov, men den typen av hjälpmedel är bra vid demonstrationer och vid försäljning för att bli lite mer självgående utan tekniska experter.

- finns det något med gällande de mekaniska.

Det vore bra att veta om det finns begränsningar som vi behöver vara medvetna om. Till exempel om det finns något max på hur många upptagare som kan staplas på varandra.

Också någon typ av grundfakta eller fysikeregler, gällande motstånd eller hur hastigheten på luften påverkar fläktarna. Även hur intressant caset är beroende på temperaturerna .

På temat mekanik, har jag märkt att vi missar den fysiska footprints, för vi har räknat väldigt mycket och så visar det sig att begränsningar och viktbegränsningar. vi på sälj vill ha en bättre uppfattning om hur stora och tung installationen blir för att uppköparna ska kunna avgöra om det är möjligt att få plats med de på deras fabrik.

Frågan är om vi måste ha kokaren och upptagaren nära varandra fysiskt, vi på sälj skulle vilja veta vad som är rimligt. Vi skulle vilja ha tumregler om hur långa avstånd rör och ventilationer kan dras.

Prissättningen är exklusive installation,men de kommer stå för installationen själva vilket gör att det kommer påverka båda parter. Det gäller både rördragning och eldragning. Vi vill leja bort installationen till elektriker och hantverkare på plats.

Just nu har vår kund tagit in en offert och de pekar på mycket höga installationskostnader. Vilket kan avgöra om affären blir av eller inte.

- Har dom specificera vad som kostar

Om vi skulle veta exakt vad det kostar skulle vi kunna göra något åt det! Tex om det är någon rördragning som blir extremt dyr kan vi istället säga att de ska skippa den delen och att vi skickar med slangar istället. Om det skulle vara så att det skulle fungera lika bra.

Om de specificerar skulle vi också ha chans att se vad som är dyrt och få chans att ändra det. Vi har försökt att be dem skicka oss nedbrytningen av kostnaden, men hittills har de inte velat göra det. Så då går vi tillbaka till utmaningen med att jobba i den här typen av miljöer med storbolag och dom har egna intressen internt. Så risken är att olika avdelningar passar på att lägga till andra typer av kostnader för att det gynnar deras budget. Så det är komplext att jobba med storbolag eftersom de inte alltid jobbar som en optimerad enhet, utan att de kan suboptimera utifrån vad som är bäst för deras

avdelning. Det finns fler steg där det kan finnas interna incitament att höja kostnaderna på deras offert ur deras perspektiv.

Oavsett vad skälen är, så måste vi få tillgång till vad kostnaderna faktiskt är. T.ex. i Thailand så var deras största bekymmer var att den rostfria rördragningen var så ofantligt dyr.

En annan del som vi inte har så mycket koll på är storbolagens säkerhetsfaktorer. Att dom har interna regler att de inte får dra rören hur som helst, vilket gör att det blir en stor extra kostnad.

Vi vill kunna artikulera för kunden att vi inte ansvarar för installationen men att vi kan ge vägledning och utbildning. Vi vill bli bättre på att kunna förutse hur stora kostnaderna blir och ha dialog och hjälpa kunderna med hur vi kan minska installationskostnaderna utan att ta ansvar för installationen .

- Vad är nästa oro hos kunderna efter kostnader?

Processfrågor! Vi säger att det behövs begränsat underhåll och då vill dom veta vad det innebär. är det byte av filter, rengöring, kommer vi behöva en heltidsanställd för att underhålla maskinen.

De är också oroliga över Up time, för det är svårt att göra avtal om det. De är också oroliga för att vårt system ska hindra deras huvudprocess, till exempel för att partiklar sätta igen.

Drift och underhåll ligger i bådass intresse, för vår del förbättrar det säljbarhet och minskar problemen och konflikt efter vi har levererat ett system, och för deras del gäller det att minska OPEX och uptime-fråga. Så det är absolut i allas intresse att systemet är så användarvänligt, enkelt och billigt i drift som möjligt.

Där kan ett uppkopplat system med larm att hjälpa att agera snabbt. Primära underhållet som filterbyte, rengöring och om det skulle behöva lags som pumpbyte.

Det är viktigt att alla komponenter.

Det är relativt lite fokus på estetik från kundernas sida, det mesta som vi har hört från kunderna är funktionalitet och säkerhet så som att vi måste undvika klämskador, värmeskador. Men från vår egen sida skulle vi nog vilja ha någon form av estetisk faktor på upptagarna, för det är ett sätt för oss att profilera oss. Vi vill att det ska se proffsigt och robust ut och inte som något hemmabygge. Det får gärna vara tydliga enheter och ha någon logga på. Om vi väl har installerat och det hänger massa lösa kablar och slappa slangar med plywoodbitar som lagningslappar kommer det inte kännas som ett pålitligt system som håller.

Det vi ska lägga krutet på det estetiska är att upptagaren, det kan vara viktigt för kommande leads och kunder som är intresserade av att skaffa ett system.

Angående ledtider så vill många ha det snabbt och billigt, men eftersom det är ett stort

- Skulle kunderna vara intresserade av att köpa ett mindre system som inte tar hela flödet om det ger en bra payback tid?

Problemet är skalbarheten i kokaren som är så stor del av kostnaden och det gör att kostnaden för resten av systemet blir förhållandevis liten. Det gör det lönsamt rent ekonomiskt ur investerings synpunkt att inte ta vara på hela luftflödet.

Det som skulle vara intressant är olika finansieringslösningar, där en tredje part är med och står för en kostnad och minskar det stora capex-utflödet i början , utan har månadskostnad som matchar den verkliga besparingen. Vi får ge bort en del av vinsten men kunden har råd med investeringen, och kan få igenom projektet. Det kommer vi nog se mer av i framtiden.

Grundplåten är kokaren och det gäller att optimera systemet efter hur stort flöde en kokare klarar av. Nästa steg är om flöden är så stora att det behövs 2 kokare, då bör det optimeras för 2 kokare, och så vidare.

Vår styrka är att vi både kan utvinna värme, energi och vatten, det är något vi bör trycka på, vi kan sen också använda den torra luften i deras huvudprocess.

I och med att vi använder ett salt så är det en fördel i livsmedelsbranschen i och med att saltet förhindrar bakterietillväxt.

Vi har styrka i skalbarheten. Att vi kan jobba med allt från små flöden till väldigt stora.

Just nu ska vi undvika kunder med speciella kemiska filter och extremt höga temperaturer i frånluften. Åter lång / kort sikt, - Värt att avstå från kunderna nu och göra en design som är förberedd för att hantera de behöver när Drupps är redo.

Interview with CSO at Drupps

- Vad ser du som utmaning i utvecklingen av ett större system än de test-moduler och pilotanläggningen som redan är utvecklade?

Den stora utmaningen som jag ser nu är att den ska få plats rent fysiskt hos de producerande företagen. Komma dit, montera in saker, få in komponenter.

Också i själva integrationen och montering att vi inte stoppar deras process allt för länge. Det måste gå snabbt och inte bli fel vid installation. Heller inte störa deras process vid drift.

Om vårt system inte fungerar ska det inte störa deras process.

- Finns det något vi kan göra för att snabba på installationen? Delar av systemet.

Det är väldigt bra om all el går att komma under drift.

För att kunna göra en snabb installation skulle vi vilja kunna testa modulerna i fabrik. Så vi vet att vi får kontakt med givare och att sensorn fungerar. Det vore också skönt med färdiga kontakter med snabbkoppling och färdigkopplat, och då kunna koppla in allt på plats, med förväntningen att det fungerar.

Upptagarenheten har inga problem att klara ett lägre flöde och styrningsmässigt vill vi veta om dom styr oss eller om vi reagerar på deras process, vi vill ha mottrycket noll över vårt system. smed givare före och efter vår enhet så vi kan med hjälp av vår fläkt anpassa efter deras tryck så vi inte alls påverkar deras process.

Kunna läsa resultat separat.

Med hjälp av en bypass ifall fläktarna skulle sluta gå i vårt system skulle vi kunna förmedla säkerhet, men till bekostnad att det skulle bli dyrare.

- Vad har du tagit med för lärdomar från legacy eller tidigare prototyper, vad som fungerade bra?

Vi har hittat bra val av fläkt med mottryck, distributionen på luften, och även distributionen av absum.

Nu tänker vi mest på det vi vill ändra på. På legacy som är två generationer bak, där är det problem med läckage, den var inte svestad ordentligt och det var designmiss. Vid en större installation.

Vi vill att det är helt tätt och att det inte läcker alls men vi kommer nog behöva förebygga för att det finns en risk att det kommer droppa eller spilla lite.

Absum K är korrosivt, men inte mot rostfritt. Abisum g är inte det och om det droppar på något så kommer det inte korrodera.

Vi vill att det inte ska droppa efter droppavskiljare, vi vill att droppa avskiljaren ska fånga dropparna.

Vi designade den förra upptagaren så den kunde testas i förväg. Fördelen med att installera på plats är att alla el-kablar och liknande bli rätt längd direkt medan om det görs i förväg mär det mycket mer noggrant.

Rör är också bra om det kan kopplas i fabrik, de måste ha plats att gå och måste ha stöd och hållare och regler säger att el och rör med vätska inte får gå ihop.

- Vilka är begränsningarna på delarna som ingår i systemet?

Placeringen av komponenter är också viktigt så det inte finns risk att det droppar vätska över elskåp. Mekanikingenjörer har gjort tester på avstånd mellan padsen och dropp-avskiljaren.

- Vad skulle du önska av systemet om du fick vad du ville?

Då skulle jag vilja testa rörsystemet i fabriken och att vi kan ha delar av rörsystemet som är standard. Istället för att installationen görs på plats. För både el och rör tar plats är det pre-brabrikerade så är det skönt om det direkt kan sättas på plats.

Så testa innan och kan garantera att det blir tätt.

Vi måste tänka på att vi kan hantera feltoleranser, annars finns risk, vi vill gärna undvika slangar för att kunna.

Det kan bli problem med temperaturskillnader så saker inte går sönder.

Det skulle vara bra om vi kunde ha en redundans i systemet med rören. Om det är möjligt att stänga av en enhet och det droppar eller om den skulle krångla.

Albumet är också dyrt att köpa nytt så det gäller också att inte slösa med albumet.

Vi skulle veta deras partikelfördelning för att kunna välja rätt filter också.

- Skulle det vara möjligt att ändra riktning på deras utflöde från deras frånluft?

Vi vill ha mycket aktiv yta så det är inget problem att fördela flödet, men alla riktningar fördelningar kostar energi och vi vill ha ett jämnt fördelat flöde.

Garanterat att det blir tätt. Göra test innan flyter på absium, typ med luft eller nått. Pre fabrikat, väldigt standard. Kunna stänga av en enhet ifall det blir stopp. Redundans. - rören. salma upp så inte allt rinner ut.

In kopplingen i elkontroll. Planera elinstallationen, el kablar, rör, kunna ha platser och stöd för rör förberett för att spara tid.

Interview with kemist at Drupps

The following is a summary of the answers to each question below, due to the semi structured interview, the answer was not structured and was best presented as a summary.

Svaveloxider: hittills är det endast från malt fabriker.

I spray dryers är det främst partiklar som proteiner. De kan klegga igen och ger näring till biofilm och växer. De täpper till. Det ska inte kunna växa i Absium.

Du kan fråga tillverkarna vad de har för partiklar, och "**particle size distribution**". Då kommer dom svara Tex pm 2.5 micro meter och anpassa filterstorlek och finmaskigheten på filtren efter det.

Det kan hjälpa att få en analys på deras luft. Det finns lagstiftning. sox och nox. Gaser går att ta bort som finns på pappersbruket. Då behövs en upptagare eller skrubber som är väldigt komplex. Det är inget som Drupps ska utveckla själva eftersom det är som att uppfinna hjulet igen.

För svårt att att göra en skrubbing eller rena luften själva, därför vi kommer tacka nej till de case och kunderna där det krävs att luften ska renas. eller om det är möjligt för en tredje part att rena luften innan.

Det finns cascader av filter i olika steg för att fånga upp artiklarna. Cyklonfilter separerar enligt vikt. Vanliga filter tar upp partiklar beroende på hur stort filtret är. Bag filter o.s.v.

Plasten klarar solljus, uv- strålning och är tålig, så det är inga problem att den står ute exponerad, den tål det.

Interview with a company (2) using a spray dryer.

- **Can you tell me about your role at the company?**

I am a Industrial project manager

- **Can you tell me about your facilities?**

We have 7 facilities, around the world, in Europe, Asia, south america, north america. The biggest dryerst is in china, and france.

The fumes are 20 - 40 ton hours of evaporative water. About 14 % in dilution.

- **Do you have any similar products that you have installed as an ad-on?**

I can not disclose too much, but we started to build our own spray dryers, because we wanted them to fit our needs better. We needed them to be able to withstand high temperatures och use the natural gasses with better efficiency

The goal is to maximize the capacity. We aim to have the process running 100% procent, but the real world does not look like that so there are stops and sometimes variation in the flow. The flow vary different between different factories, but the process is very stable. If we have around 40 nozzles, and we want to change the flow, we turn them off one at a time in steps so it is almost continuous. So we control the pressure, inlet flow and temp when we do the changes in production flow. If you want to take care of the outlet air maybe you have to be a little adaptable.

We have a constant flow, but when we change the inlet slurry, you will change gas and variable flow depending on the drying varierande flöde -

Slurry - 75 - 80 % water and the rest is slicica. For the tire industry. +/- 5% Water.

- **Do you have and know the limit of how much load you can put on the roof?**

3 plants 2010. - no standard.

We have built three similar plants and it is very standardized in recent factories. The inlet air is 700 degrees celsius so the startup and the shutdown has to be slow and we use special alloys and are still close to the mechanical limit.

Outlet we generally build it on the roof and we use a chimney. Particle filter. back filter it can be leak

We catch silica in the back filter and cyclone filter. The filter we use is a back filter with sleeves, no chemical filter.

- **Would it be a problem to change the design of the chimney?**

No, it would not be a problem to change the chimney. We know there is a lot of heat waste in the outlet, so we are far from using all the enthalpy in the heat. the problem is to maximize the heat exchange. The fumes in the outlet air is about 80-90 degrees and that is not so high. We could condense the water and give us some energy and water. The difficulty is the high temperature. With a heat exchanger we could only heat up the inlet air to 70-80 degrees, not more. we have to do 700 degrees. So if we do not reach 200 degrees, it is a lot of money for not a lot, and it not close to 700 degrees.

- **Let's say we could do 300 degrees. What features and functionalities do you think are important for the product?**

Except for saving water, the main target is to reduce Co2 without increasing the cost.

Number one is reliability. First of all, it does not prevent the dryer from running. We are considered a biomass boiler, it has 85% running time. But we need a lot

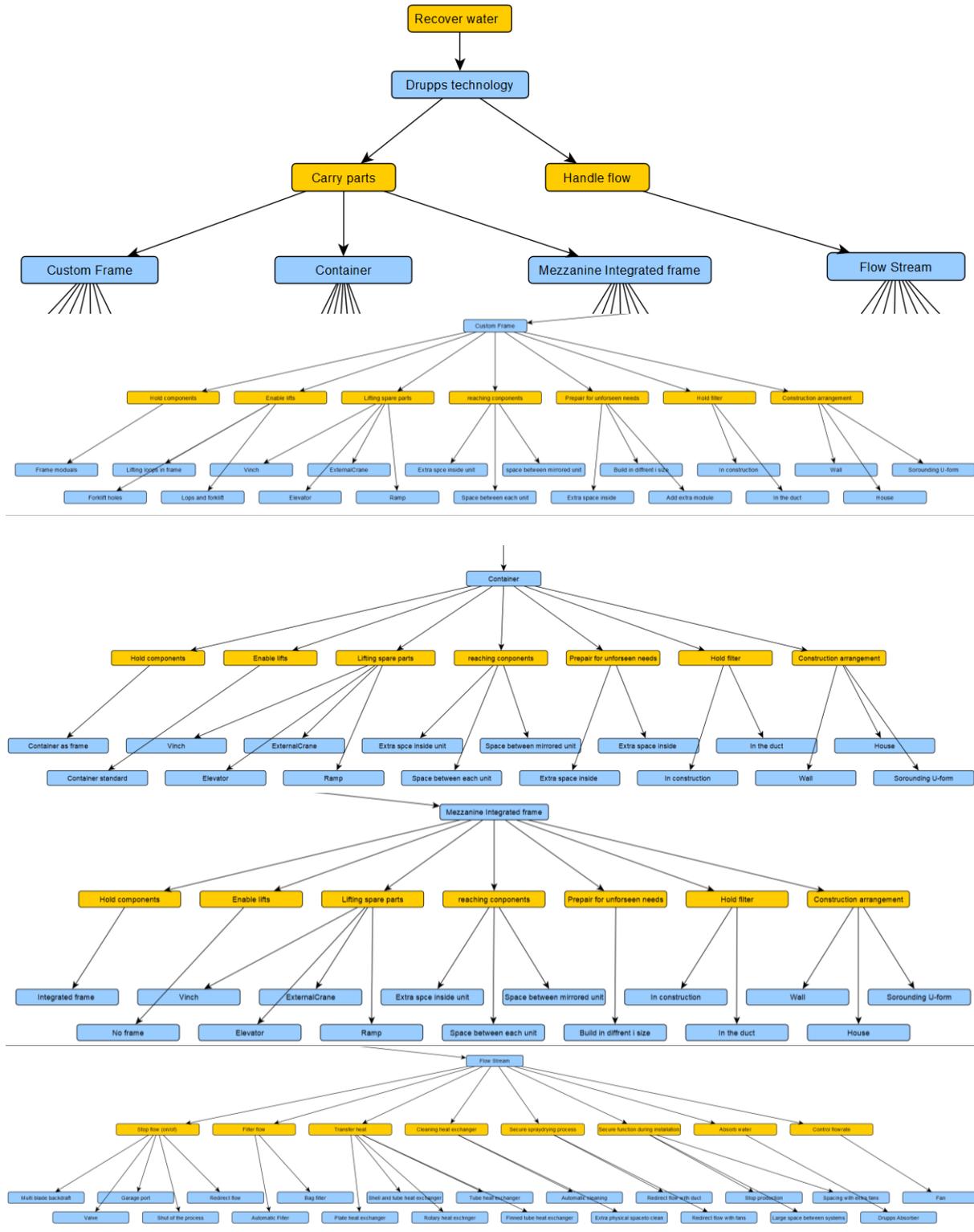
The maintenance, that we can do it any time. Simplicity, so people know what is going on and understand it, and the equipment.

We have our own service personnel, but good support is valuable. We do not want to increase cost.

- **When you design your own spray dryer what do you think about?**

We think about temperature differences, that can easily be a problem, but I can not tell you too much about specific parts. But temperature stability is important to think about.

Appendix B - Function mean modeling





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