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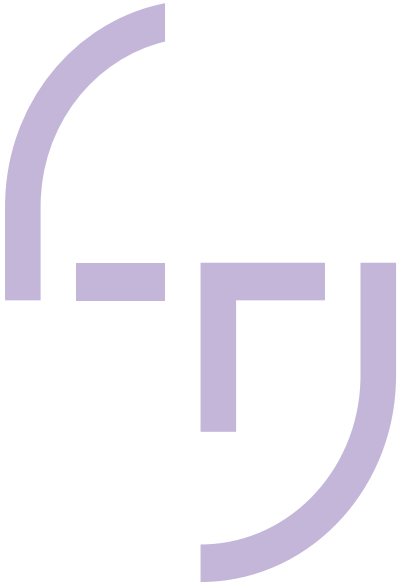

Finnish hydroponic greenhouse concept to the US market

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MASTER'S THESIS

May 2022

Master's Degree Program in Technology Management

TIIVISTELMÄ

Tampereen ammattikorkeakoulu
Ylempi ammattikorkeakoulu
Teknologiaosaamisen johtaminen

LAMBERG OTTO:
Finnish hydroponic greenhouse concept to the US market

Opinnäytetyö 79 sivua, joista liitteitä 12 sivua
Toukokuu 2022

Nopeasti kasvava teollistunut kasvihuonemarkkina tuo mukanaan uusia mahdollisuuksia, ja etenkin Yhdysvaltojen markkinassa on paljon potentiaalia, sillä siellä kasvihuoneiden määrä on maan pinta-alaan nähden pieni, verrattuna esimerkiksi Eurooppaan. Tämän opinnäytetyön tarkoituksena on tutustua paremmin Yhdysvaltojen jo olemassa olevaan kasvihuonemarkkinaan ja rakennettuihin kasvihuoneprojekteihin sekä tunnistaa sieltä kehityskohtia.

Tutkimus suoritettiin tekemällä ensin Delfoi haastattelu kahdelle henkilölle, joilla on kokemus kasvihuonetoimituksesta ja rakentamisesta. Tämän haastattelun perusteella aihetta saatiin rajattua, jonka perusteella laadittiin verkkokysely. Kyseinen verkkokysely lähetettiin mahdollisimman monelle jo kasvihuoneen rakentaneelle henkilölle. Kyselyn kohdeyleisönä olivat: projektipäällikkö, projektin jäsen, rahoittaja, yrittäjä, sekä (pää)kasvattaja. Kyselyssä haettiin vahvistusta Delfoi haastattelussa esiin tulleille aiheille. Kyselyn pohjalta laadittiin konkreettisia kehitysehdotuksia ja työkaluja, jolla Yhdysvaltojen markkinaan olisi hyvä edetä työn tilanneella yrityksellä, Finn Growers Oy:lla.

Opinnäytetyön lopputuloksena syntyi käsikirja, jossa käsitellään Delfoi haastatteluista ja verkkokyselyistä saatuja vastauksia. Käsikirjan tarkoituksena on palvella tulevaisuuden kasvihuoneprojekteja, johon on kootusti tunnistettu projekteissa esiin tulleita kohtia, jotka voitaisiin tehdä paremmin.

Avainsanat: kasvihuone, konsepti, markkina, projekti, käsikirja

ABSTRACT

Tampere University of Applied Sciences
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LAMBERG OTTO 2:
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Bachelor's thesis 79 pages, appendices 12 pages
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Rapidly growing industrialized greenhouse business has advantages and especially the US market has lot of potential since number of greenhouses is small when thinking about the size of the continent and compared for example to the EU. Purpose of this thesis is to familiarize existing greenhouse market and ready greenhouse projects in US and find aspects to improve those projects. Outcome of this thesis is a concept like product from greenhouse delivery project which includes all the aspects that should take into consideration in this kind of project.

Research was done by first carrying out a Delfoy interview for two persons how have demonstrated knowledge from greenhouse delivery project and construction. With the help of this interview thesis subject was easier to narrow down and from that interview online questionnaire were prepared. Questionnaire was sent as many people as possible who have built greenhouse and the target audience of this questionnaire was: project manager, member of project organization, investor, entrepreneur and, (head) grower. Purpose of this questionnaire was to have confirmation to the subjects which was brought up in the Delfoy interview. Based on the result from the questionnaire and Delfoy interview concrete development plans and tools was made to the client of this thesis, Finn Growers, on how they could approach to the US greenhouse market.

As a result of this thesis is a handbook for Finnish hydroponic greenhouse to the US market where is processed the findings from Delfoy interviews but also from questionnaire. The purpose of the handbook is to help and guide the future greenhouse projects for making things better and more efficient than before.

Key words: greenhouse, concept, market, project, handbook

CONTENTS

ABBREVIATIONS AND TERMS

UN	United Nations is an international organization currently with 193 member states and its purpose is to maintain international peace and security
CO_2	Carbon dioxide. In this thesis CO_2 means harmful greenhouse gas in Earth's atmosphere
NFT	Nutrient film technique. Cultivation technique in a greenhouse cultivation where thing layer of nutrient water is used to nourish plants
DFT	Deep film technique. Cultivation technique in a greenhouse cultivation where plants are floating for example in a raft and plants roots are in the water
UNCCD	United Nations Convention to Combat Desertification is a convention to combat and mitigate the effects drought

1 INTRODUCTION

When United Nations (UN) was discovered in 1950 world population was around 2.6 billion. In 1999 population reached 6 billion and it's expected that population will be 9.7 billion in 2050. (UN 2022)

World population is growing all the time, and this will increase demand on food supply. In recent decades we have seen more effects on climate change which have had big impact on food production as well. Rising temperatures and atmospheric CO_2 levels among other factors will lead to lower agricultural yields and impose threat to food and feed safety. This creates a dilemma where existing agriculture needs to produce more but at the same it's expected that yield production will decrease in traditional farming. (Farooq, Pisante 2019, 20-21)

Agricultural growth needs to happen in sustainable way and greenhouses can provide one respectable solution. It has been shown that in the greenhouse you can grow crops no matter the location. Locally grown products, higher yield per area, longer harvest periods and better control in growing environment makes greenhouse cultivation a feasible solution. (Paksoy, Beyhan 2014, 533)

This thesis was ordered by Finn Growers Oy. The Company was established in 2021 and its focus is on research, develop and pilot low carbon environment footprint in greenhouse cultivation and technology. Finn Growers Oy wants to be involved in creating a sustainable future.

Greenhouse cultivation and especially complete greenhouse project delivery does not have an established concept. Greenhouse concept means full delivery concept for greenhouses using Nutrient film technique (NFT) cultivation and it consists for example, greenhouse size and basic layout, and equipment selection. This is where Finn Growers Oy sees potential. There is business opportunity to develop and establish modular model and concept in rapidly growing greenhouse cultivation business. By establishing modular model and concept in greenhouse delivery you can construct and operate greenhouse which gives you the best quality and the highest yield in a sustainable way.

2 WHAT IS A MODERN GREENHOUSE?

To understand better a modern greenhouse is good to look at the evolution of greenhouses. Already in the early 19th century farmers in the Northern Europe built glasshouses as they put together little boxes from wood and a glass lid which were the first “greenhouses” then. This helped farmers to start their plants earlier in the spring and when weather turned colder, they were able to extend the season. In the mid 19th century farmers were already growing grapes in greenhouses. Also, that time greenhouses became bigger to allow people enter inside and roofs were angled so rainwater would run off the roof and eventually it was collected and used for irrigation. (Dol 2020, 8)

Since 1850s look of the greenhouse has changed quite a bit but in the last 35 years outside appearance of the greenhouse hasn’t changed that much. However, they have become bigger and taller and building materials have developed into more lighter materials which allows more sunlight inside the greenhouse. Most significant changes have happened inside the greenhouses. Major milestones in the development of greenhouses have been in the 80s when more advanced irrigation systems were introduced, and computers started controlling all systems. From picture 1 and 2 can be seen what greenhouse looks like from the outside and inside. (Dol 2020, 8-9)

When designing a greenhouse first, and biggest factor is that it needs to provide optimal climate conditions for the plants inside. In addition, you need to take into consideration the factors outside of the greenhouse such as wind, rain, snow, and crop loads. For example, in Southwest Florida there is not much rain during wintertime. In fact, there can be a whole month without any rain but when it comes to summertime it rains heavily almost every day. (Von Zabeltitz 2011, 87-88)

PICTURE 1. Modern greenhouse production site. (Finn Growers Oy, key presentation material 2022)

PICTURE 2. Modern greenhouse cultivation area. (Finn Growers Oy, key presentation material 2022)

Typically, a greenhouse consists of following areas:

- Storage and seeding area
- Germination room
- Growing area (e.g., growing tables)
- Packing & storage area
- Conveyor belts
- Offices

From figure 1 can be seen greenhouse layout sketch from Southwest Florida greenhouse.

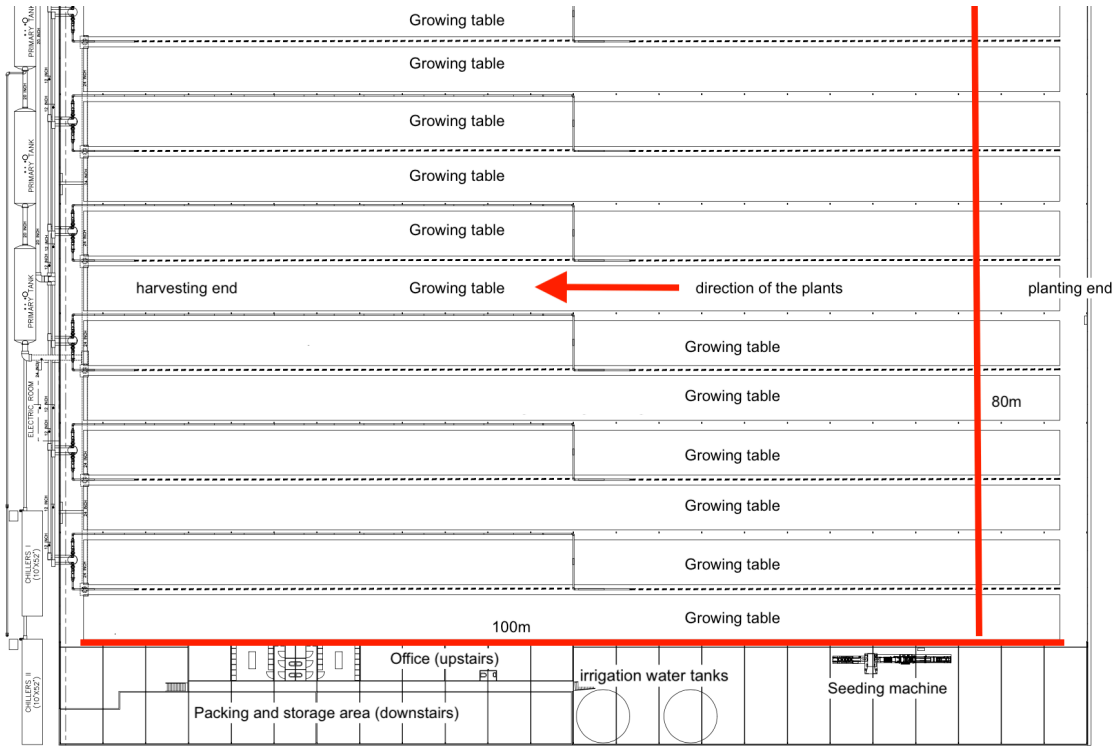

FIGURE 1. Layout sketch from greenhouse

Today's greenhouse can be fully automated from seeding the plant to harvesting and packing. Human will only observe and monitor the whole process. It's expected that in the future level of Artificial Intelligence (AI) might be growing. In the Southwest Florida greenhouse planting, harvesting, and packing was done manually.

2.1 Greenhouse cultivation methods

When it comes to greenhouse cultivation there's not one method which is used in every greenhouse. Three commonly used methods in greenhouse cultivation are:

- Aquaponic
- Aeroponic
- Hydroponic

2.1.1 Aquaponic

In Aquaponic cultivation animal aquaculture e.g., fish is combined with plant production for saving resources. Aquaponic is part of hydroponic technique where irrigation system can be the same, only living animal culture is added to the system.

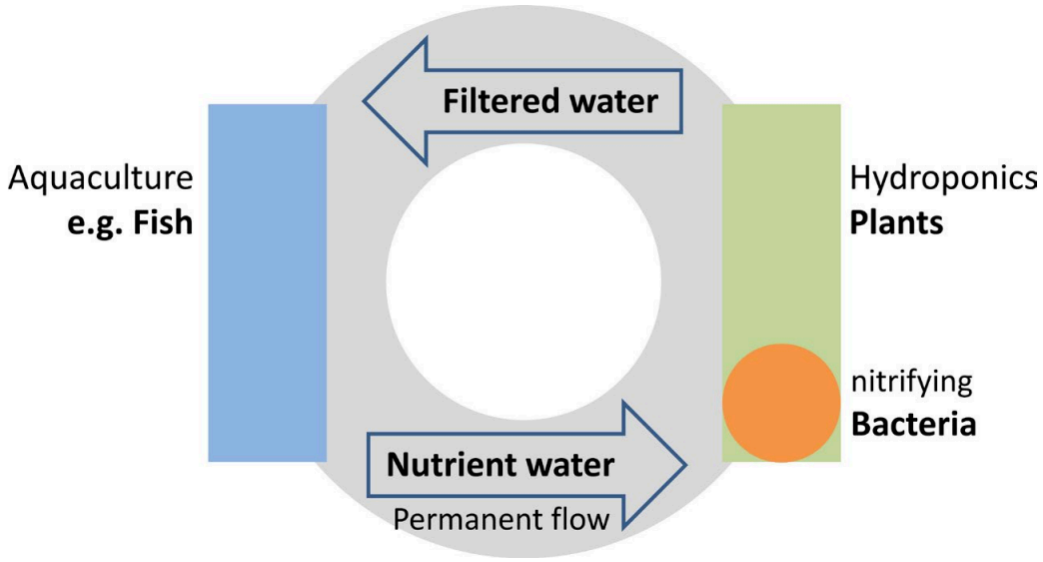

FIGURE 2. Basic principle of aquaponic cultivation. (The aquaponic principle 2022)

In a large scale this is not popular greenhouse cultivation method simply because you need to have living animals next to the plants and that is not possible every time nor efficient way to cultivate.

2.1.2 Aeroponic

In Aeroponic cultivation plant roots are exposed to small droplets which contains nutrient enriched water, and this solution is guided through nozzle and that sprays droplets into the root of the plant. (Getting to the roots of aeroponic indoor farming 24.6.2020)

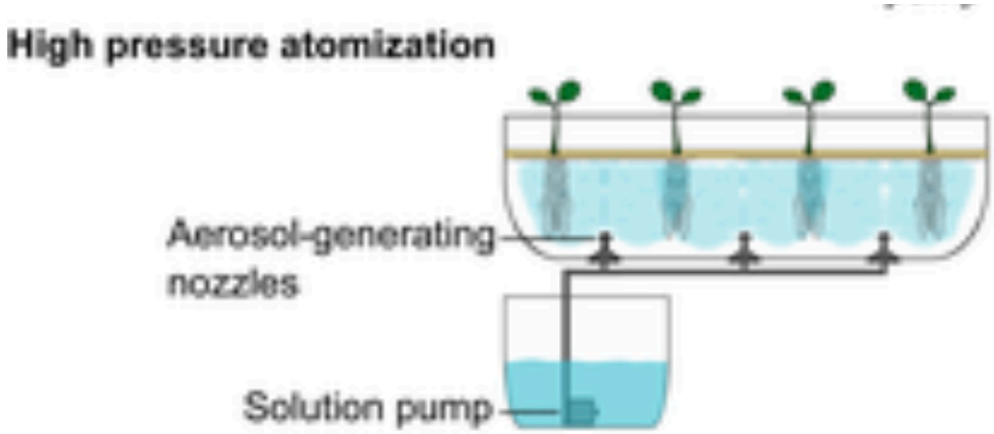

FIGURE 3. Basic principle of aeroponic cultivation. (Getting to the roots of aeroponic indoor farming 2022)

Aeroponic cultivation is mostly used in smaller scale because of high investment and management costs. (Goddek 2019, 92)

2.1.3 Hydroponic

Hydroponic cultivation can be divided into two different methods

- Deep flow technique (DFT)
- Nutrient film technique (NFT)

In deep flow technique (DFT) cultivation of the plants happens on floating or hanging support, such as rafts, panels or boards in containers filled with 10-20 cm of nutrient solution. One of the simplest systems is to have 10-30 cm deep

tanks and have those tanks equipped with floating rafts that provide support to the plant while roots are in the water. (Goddek 2019, 90)

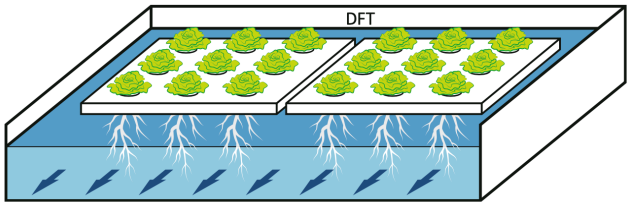

FIGURE 4. Basic principle of DFT cultivation. (Goddek 2019, 90)

Benefits of this technique are that once the system is set up, management and operation costs are low, and level of automation is low if existing at all. Basically, plants drift in the water until they are ready to be harvested. However, downside is that if water gets too warm you might have for example root disease and in such a vast amount of water it's difficult to get temperature down and get rid of the disease. (Goddek 2019, 90-91)

In nutrient film technique (NFT) plants are planted in a gutter and gutters are laid in growing table. Then, water with right nutrients is pumped from nutrient tank to the plants and 1-2 cm layer of water flows through gutter and excess water circulates back to the nutrient tank. When water flows through gutter, plant roots absorb water and nutrients. (Goddek 2019, 91)

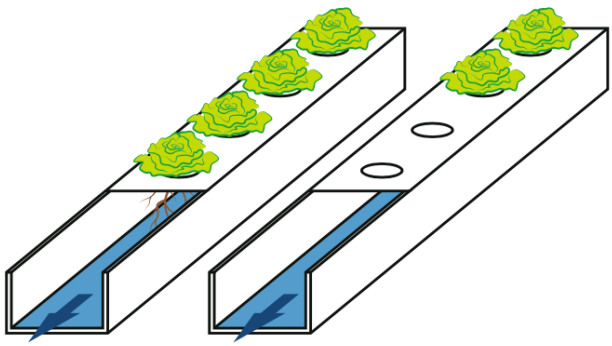

FIGURE 5. Basic principle of NFT cultivation. (Goddek 2019, 91)

Benefits of this technique are that there's a great potential for high automation rate and low labor costs since all areas from planting to packing the plant can be automate and it's easy to manage optimal plant density during crop cycle. However, because water film is thing in the system it's very vulnerable if you lost source of water for example in a water pump failure. This is the most common way to cultivate in a greenhouse. (Goddek 2019, 91)

2.2 Traditional open land farming versus hydroponic greenhouse cultivation

Agricultural food production is considered one of the key ecological services which are in danger. Climate change is affecting agricultural food production where it generates new pest and disease risks, extreme weather conditions and global temperature warming. (Goddek, Joyce, Kotzen, Burnell 2019, 20)

2.2.1 Traditional open land farming

In the past few decades food production productivity is increased by 90% with increased cropping intensity and better crop cycle but only 10% has come from land expansion. Already in 2017, The United Nations Convention to Combat Desertification (UNCCD) report there are notes from worrying trends affecting food production, including land degradation, loss of biodiversity and ecosystems, as well as widening gap between food production and demand. (Goddek et al 2019, 20)

World's land surface approximately 20-30% is considered usable for agricultural practices. This availability is decreasing and there is shortage of suitable land where it's most needed, close to population centers. Soil degradation is a major factor to this decline, which consists of:

- Displacement (wind and water erosion)
- Internal soil chemical and physical deterioration (loss of nutrients and/or organic matter etc.)

In four decades from the early 1960s to late 1990s relation to population growth, arable land per capita has declined about 40%. Term “arable” land means availability of adequate nutrients to support crop production. In addition, consumption of fertilizers is increased from 90 kg/ha to 135 kg/ha in just 11 years (2002-2013). Increased use of fertilizers often means unnecessary overdoses of nitrate and phosphates in aquatic ecosystems. (Goddek, et al 2019, 22)

Modern agricultural practices and farming requires lot of water and worldwide agriculture sector consumes approx. 70% of the world’s freshwater and that rate exceeds 90% in most of the world’s least developed countries. In the future when population grows it’s estimated that by 2050 agriculture will need to produce 60% more food globally than today and in some developing countries this demand is 100%. Latest forecasts expect that water availability will be declining in the near future in all countries. Water availability is at risk so there’s a need to develop agricultural techniques that requires low water input, and those techniques also needs to improve ecological management of wastewater through better water reuse. (Goddek, et al 2019, 25-26)

2.2.2 Hydroponic greenhouse cultivation

Greenhouse cultivation has advantages compared to traditional open field farming. For example, traditional farming is not possible throughout the year in rural areas or in tropical regions. Most common reason is that it is either too hot or cold to cultivate. With greenhouse cultivation all this can be avoided since one major benefit in greenhouse cultivation is that optimal climate conditions can be created for crop growth and crop is protected from outside pests. (Von Zabeltitz 2011, 4-14)

If the greenhouse is designed correct way to match and protect from climate outside it can protect crops almost from everything, such as:

- High solar radiation with shading curtains
- Low temperatures with heating system
- High temperatures with cooling system
- Heavy rainfall with proper roof and drain systems

- Working conditions of people with climate control
- Etc. (Von Zabeltitz 2011, 14-16)

Like mentioned in the previous chapter source of fresh water is a major factor in many regions and farming uses approx. 70% of all the fresh water in the world. In greenhouse cultivation the use of water is much lower than in an open field farming, mainly because:

- Irrigation water can be circulated
- Rainwater can be collected in storage tanks and used for irrigation
- Irrigation is done with drip irrigation which saves water (Von Zabeltitz 2011, 440-445)

In table 1 can be seen what the loss of water in greenhouse cultivation is compared to open field farming. Also, table 2 shows that the water use efficiency (WUE) is much higher in a greenhouse cultivation than in an open field.

TABLE 1. Loss of water in different irrigation systems. (Von Zabeltitz 2011, 445)

Drip irrigation	10-20%
Sprinkler irrigation	30-50%
Furrow irrigation	50-60%

TABLE 2. Water usage efficiency of tomato crops with different climate systems and using different growing systems (Von Zabeltitz 2011, 448, modified)

Growing conditions	**Country**	**WUE (kg/m^3)**
Open field soil cultivation	Israel	17
Unheated plastic-film greenhouse		
Soil cultivation	Israel	33
Climate controlled greenhouse		
Open soil-less cultivation	Netherlands	45
Closed soil-less cultivation	Netherlands	60

Almost around the globe the balance between rain and sun is uneven. When cultivation happens in a climate-controlled greenhouse, roofs can be used for collecting rainwater and store it in storage tanks. This way freshwater usage can be even lower. (Von Zabeltitz 2011, 451)

In open field farming you can't control the weather or the climate in any way but in greenhouse you can. Many of the species grown in open land or greenhouse are warm-season species. Usually, plants are killed either with frost or high heat, when temperature goes below 0°C or when temperature goes above 33°C. In addition, quality, growth pace and yield are affected if temperature is below 12°C or above 30°C for a long period of time. Optimal temperature range during day is 22-28°C and in the nighttime 15-20°C. This kind of climate can be created and controlled only in the greenhouse. (Von Zabeltitz 2011, 73-74)

However, greenhouse cultivation does have some disadvantages as well:

- Cost – investment cost of the greenhouse and full system can be extensive. Many aspects effects on the cost such as level of automation, location, and size of the greenhouse
- Rapid spread of decease – once it enters to the system and since irrigation water is reused deceases can spread into the whole production rapidly
- Irrigation system pump failure or cooling or heating system failure – irrigation pump failure can lead to a total loss of production. Plants can survive a certain period without water but if irrigation is out of order more than 12 hours, on many occasions whole production is lost (Mohammed 2018, 9)

2.3 Hydroponic cultivation in a greenhouse using NFT

Hydroponic cultivation is a soilless form of agriculture and that is dependent on a water-enriched nutrient solution, which is essential for the growth of plants. Like mentioned in the previous chapters the water film in the gutter is thin which means that good water supply is essential. Nutrient solution contains many different macro elements such as, nitrogen, phosphorous, potassium, calcium, magnesium, and sulfur which are all essential for plant growth. Plants grow in soilless

environment but to be able to grow the plants needs mechanical support of inert medium. Typically, inert medium is:

- Rockwool
- Perlite
- Coconut fiber
- Sand
- Peat moss

Inert medium keeps plant in right place and nutrients flow through plant roots. (Mohammed 2018, 1-3)

In NFT system plant seeds are planted in soilless inert medium such as peat moss and together they form a pot. Then, pots are planted in a channel called gutters and inside gutters thin film of nutrient enriched water flows through it and plant roots get their nutrition like seen in figure 6. Needed nutrients are mixed accordingly in the mixer tank from which it then flows or is being pumped to the gutter system and eventually to the plant roots. (Mohammed 2018, 6)

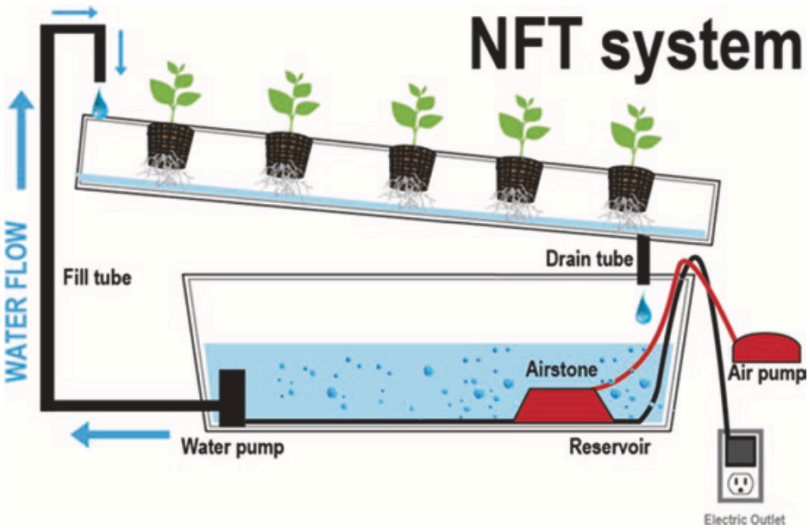

FIGURE 6. Basic function of NFT system. (Mohammed 2018, 6)

2.4 Material logistics and deliveries in a greenhouse project

In a greenhouse project where more than 40 containers full of components, parts and machines are transported from Finland to US material logistics is important part of whole project. In order to have project moving within the schedule material logistics needs to be planned carefully in advance.

Material logistics deliveries includes many aspects that needs to be taken into consideration. Not only materials need to be brought to the site and unloaded, but they also most likely need to be moved around the site. And as long as project is active material logistics is likely to take significant part of each working day, which means that challenges created by these functions are constant. (Sullivan, 2010, 67)

Like mentioned material logistics most likely takes significant part of each working day. When planning for unloading containers or trucks, it's important to think about the volume and flow of the materials, and the capacity to unload them. Let's say that there is a 10 hour's period of unloading and each delivery takes an hour to unload, there can't be planned 15 deliveries for one day. Of course, this sounds obvious but from time to time there are too many deliveries planned for one day. (Sullivan 2010, 36)

Handling the material at the construction site in the right way is important. It's important to make sure that you store all the materials on the site in a proper way, for example you can have material that needs to be covered from the rain or sun. If materials are left here and there on the site, it's easy to lose material when they are needed but also it might in your way. If you need to move the material multiple times, this creates a risk that materials might damage. Proper material handling needs to have right tools, machines, and skilled people so it can be done safely and effectively. (Sullivan 2010, 83-86)

2.5 Project management

Greenhouse construction project is enormous. In the project you have many pieces that needs to be put together starting from land zoning and permits to installation of the cultivation technique and everything between them. Normally, greenhouse projects take about 1.5-2 years to complete. Project management has a big role and project manager has multiple pieces to keep them in order so that the project will be finished and successful.

But what is really a project? What are the definitions of a project? In the figure 7 are good definitions what project is and what is not.

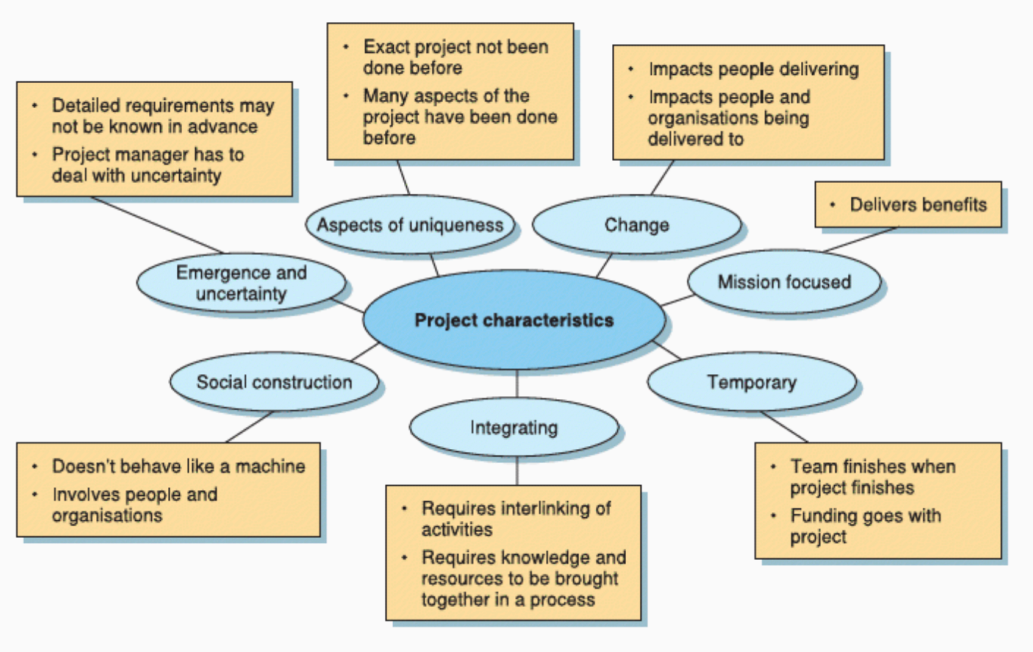

FIGURE 7. Project definitions (Maylor, 2010, 7)

In the Southwest Florida greenhouse project at least following definitions match from the project characteristics:

- Temporary – greenhouse has a beginning and once it finished it will change to operational factory
- Mission focused – when greenhouse is ready it will produce herbs and lettuce locally to the people near by
- Aspects of uniqueness – this kind of greenhouse was first of its kind in Southwest Florida and for most of the project organization

- Emergence and uncertainty – there were many uncertainties during the project what project manager and project organization were needed to handle
- Integrating – in the greenhouse project many different pieces were needed to put together to make greenhouse complete (Maylor 2010, 7)

In the project management, there are two major aspects:

- Leadership – leading the people on the project
- Management – defining and coordinating the work to be done

Leadership is the side of project management what project is all about, getting people to do the assigned tasks. Leadership requires good human knowledge and the ability to skillfully apply appropriate interpersonal skills. (Heerkens, 2014 chapter 1).

Management part of these two aspects involves the knowledge and understanding of project management process such as creating an execution schedule or how to maintain right level of control throughout the project. (Heerkens 2014, chapter 1).

Good project managers (PM) can handle both aspects, leadership, and management in a right proportion but as always, these needs to go hand in hand. PM needs to have procedures how to ensure that things are getting done but also, PM needs to gain the trust and respect of the project team so people will follow to the given direction and sometimes it's difficult to get people on the same board. (Campbell 2014, chapter 2).

There are also many other skills and topics which PM needs to have, and those skills can be divided into the hard skills (or topics) and soft skills. The hard topics normally covers aspects such as business case, cost control and work breakdown when soft skills can be described in like of health and safety, leadership, communication and marketing and sales. Whoever the person is who has the project manager title has enormously big responsibility and impact on the project which he or she is leading and managing. (Lester 2007, 5)

2.6 Land zoning and permit process in the greenhouse project

In US land zoning is the “mother of all the city rules” and universally it’s used almost in every American city, towns, suburbs, and villages. There are three main rules that land and building zoning always follows:

- Their use or the activities that happens within them (categorized in residential, commercial, industrial etc.)
- Their shape (for example building height)
- Their size (the amount of building that can be placed on a unit of land)

Fact is that these categories are the standards of land zoning, and they are often presented as part of definition. In addition, there can also be another categorization, which is:

- Agricultural
- Residential
- Commercial (business)
- Industrial (manufacturing) (Hirt 2014, 31-32)

When greenhouse land zoning permit is in process basically it is possible to have two outcomes from the categorization. Either it can be treated as an agricultural or as an industrial site. In some states where greenhouses have been built, they have been categorized as an industrial site but in some other states like in Southwest Florida case greenhouse was categorized as agricultural site.

If it is categorized as an industrial site that might dramatically increase costs in the project since some states legislations demand that in industrial site, there is need to have sprinkler system throughout the building. But if it is treated as an agricultural site there is most likely no such demand for sprinkler system. In the Southwest Florida project handheld extinguishers were enough.

2.7 Commissioning and production ramp-up

When the greenhouse construction work is nearly finished comes the time to do commissioning for the equipment's and applications and at the same time or shortly after follows the production ramp-up. In a typical modern greenhouse, there are many machines and applications that needs commissioning, for example irrigation system, seeding machine, growing tables and so on. Commissioning can be easily divided into three different categories, and together these form a commissioning:

1. Pre-commissioning – where for example electrical motor is installed but it requires motor loop testing
2. Commissioning – where for example irrigation water system is put into initial operation. This operation connects different functions together such as pumps, leak test of piping, operational logic and so on.
3. Start-up – where the greenhouse is brought into actual operation. (Killcross, 2012, 12).

Furthermore, commissioning can be divided into three smaller phases:

- Prepare – activities to be taken so that commissioning is possible such as gathering information, develop the schedule and create documentation
- Implement – where "commissioning" traditionally happens such as installation, checking and start-up of the new equipment
- Close out – where ensuring that all the paperwork systems and trials are complete and that the plant or application has met its acceptance criteria. This phase is often the most neglected phase in commissioning. (Killcross 2012, 13).

In all, all these phases are important in commissioning but if first step is neglected and there's no proper plan on how to execute commissioning it's most likely not going to success.

Hand in hand with commissioning goes production ramp-up. Term ramp-up is used to describe the anticipated increase in production and production demand. Alternatively, ramp-up can be used to describe the period between product development and maximum capacity utilization. Figure 8 gives a good example what different phases are included inside the production ramp-up process. (Errasti 2013, 252)

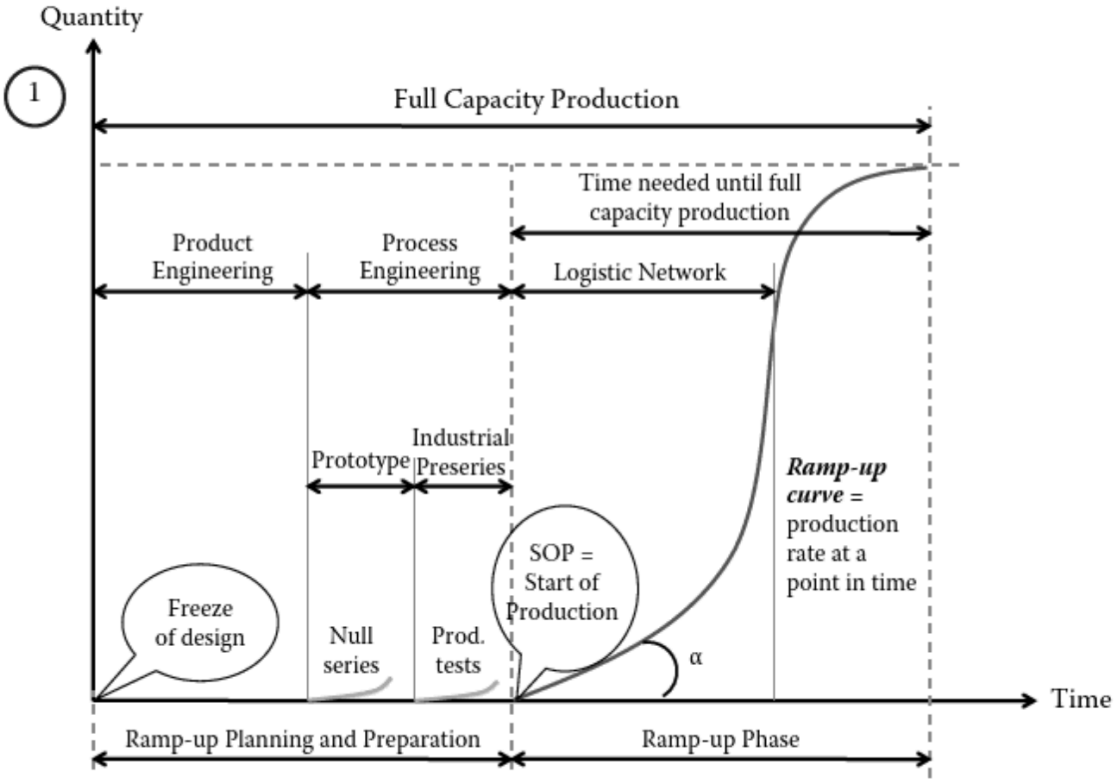

FIGURE 8. Production ramp-up phases. (Errasti, 2013, 252)

During and after production ramp-up there are other processes which will support the ramp-up process and those must be defined, tested, taught, and implemented. One of these is procedure for quality problems when they occur since, most of the delays in facility implementation are caused by quality problems. Second important phase is to write down product documentation and establish product variances and features. Third important phase is to implement methods and tools on how to plan and test the product as well as operative control to production process. In the integration at least these aspects should be considered:

- Production yield testing and optimization
- Production process development and optimization
- Plant design and development
- Operative production planning and control (Errasti, 2013, 254-255)

During ramp-up it’s expected that there are production down-times, delays, and loss of production especially when everything is new, and it’s put in operation for the first time. (Errasti 2013, 255)

3 FINNISH GREENHOUSE CONCEPT TO THE US MARKET

This master thesis is part of bigger project which purpose is to export Finnish hydroponic greenhouse growing technology concept to the US market.

3.1 Research and develop low carbon footprint and energy efficient greenhouse concept

Part of this project is to develop and establish modular model and concept in greenhouse cultivation where investments and operational costs support cost effective greenhouse cultivation. The goal needs to be that you have a greenhouse, and you can grow different kinds (if needed) in own rooms or sections under the same roof but in a way that for example they use same irrigation water, packing area, packing material logistics, cold storage etc.

Finn Growers Oy is considering dividing greenhouse concept in three (3) different sizes:

- Small (S), 1 hectare
- Medium (M), 3 hectares
- Large (L), 5 hectares

By narrowing down greenhouse sizes in to three options, it eliminates having multiple different complex designs in different sizes. All these different concepts will be optimized including construction costs, operating costs, and payback period of the invested capital. In addition, it is needed to define scope for technology to be used in this concept so that different technology providers can provide cost estimations from their technologies.

Also, big part of this topic is modularization. Since greenhouse technology comes from Finland to US market the distance is long. This means that it's important to design concept that is easy to deliver from Finland and construct in US. In other words, there is a high rate of parts coming from Finland and less from US. Achieving high modularization rate, it's needed to design and develop models where project lead time is as short as possible. One way to achieve this is by designing modular greenhouse models.

3.2 Local environmental legislations and effect in costs

As mentioned in chapter 1 that greenhouse technology and concept is not mature enough that it has established concept. This also means that it doesn't have clear boundaries in construction and environmental legislations. Construction legislation in this case means for example structural design such as wind load and in environmental legislation for example permission to collect rainwater. Both legislations vary between states and even inside states between counties. This might cause big delays and unexpected expenses on greenhouse projects if these are not taken into consideration straight from the beginning.

3.3 Preliminary study for possible research and development collaboration with US universities

Currently United States doesn't have any university which offers greenhouse cultivation as a subject to study which means that even though greenhouse cultivation is rapidly growing business in United States, universities can't provide any background knowledge. It would be big benefit for universities if they could offer studies which are related to greenhouse cultivation. Purpose is to do preliminary study for universities which could be interested in developing studies around greenhouse cultivation.

3.4 Finnish greenhouse delivery concept

Like mentioned in the chapter 1 greenhouse delivery doesn't have structured design or concept. Often greenhouse is being bought by group of investors who wants to be a part of rapidly growing greenhouse business. This means that the investors might not have knowledge when it comes to greenhouse delivery and its technology. Here is the potential market for Finn Growers Oy where you help potential investors or buyers to identify and propose the right solutions for their needs. This thesis will provide Finn Growers Oy handbook for the future greenhouse projects on how those projects could be done in a better way.

Greenhouse concept means full delivery concept for three different size greenhouses using NFT cultivation. Concept consists of following areas:

- Greenhouse basic layout
- Equipment layout
    - Growing tables
    - Seeding, harvesting, and packing equipment’s
- Roof type, glass roof (opening or not opening roof)
- Cooling and ventilation system
- Climate operating system
- Level of automation (low, medium, full)
- Lighting and curtain system

4 RESEARCH METHODS

There are not many books and literature regarding on how to build greenhouses. Also, if it's wanted to establish greenhouse project concept, history should be investigate and see what has been done in the previous greenhouse projects in US.

In this thesis the research method will be qualitative research. Qualitative research is based on interpretation, and you can focus on history and the value to the research comes from person experiences not from values or numbers. In qualitative research a person is always someway under study. (Hilkka 2021, 11).

Before qualitative research to help understand better the possible grievances in greenhouse deliveries and concept there will be pre study using Delfoy interview. This will be conducted by interviewing two persons who have strong knowledge from greenhouse deliveries. Using Delfoy interview the purpose was to have better understanding from greenhouse projects.

After interviewing two persons, the interviews were transcript and further transferred into a mind map. When transcript material is transferred into a mind map the idea is to identify common things and divide them into groups by theme. Open and theme question mind maps can be found from appendix 2 and 3. Interviewees used their experiences from their last greenhouse project which was in 2019-2021 in Southwest Florida. Questions for these interviews can be found on appendix 1

Topics will be analyzed by case study and that will be done to already built greenhouses in US. Practically, sending a questionnaire to the people who have built greenhouses in the US. Questionnaire will have questions with 2-6 different answers where to choose. Using Delfoy interview as a pre study that should help determining right questions and answers to the questionnaire.

Case study is often good tool to use when the purpose of the job or in this case thesis is to produce development plans and ideas. Case study often gives you answer to the questions “how?” and “why?”. (Ojasalo 2015, 52). Case study steps can be described like shown on figure 9.

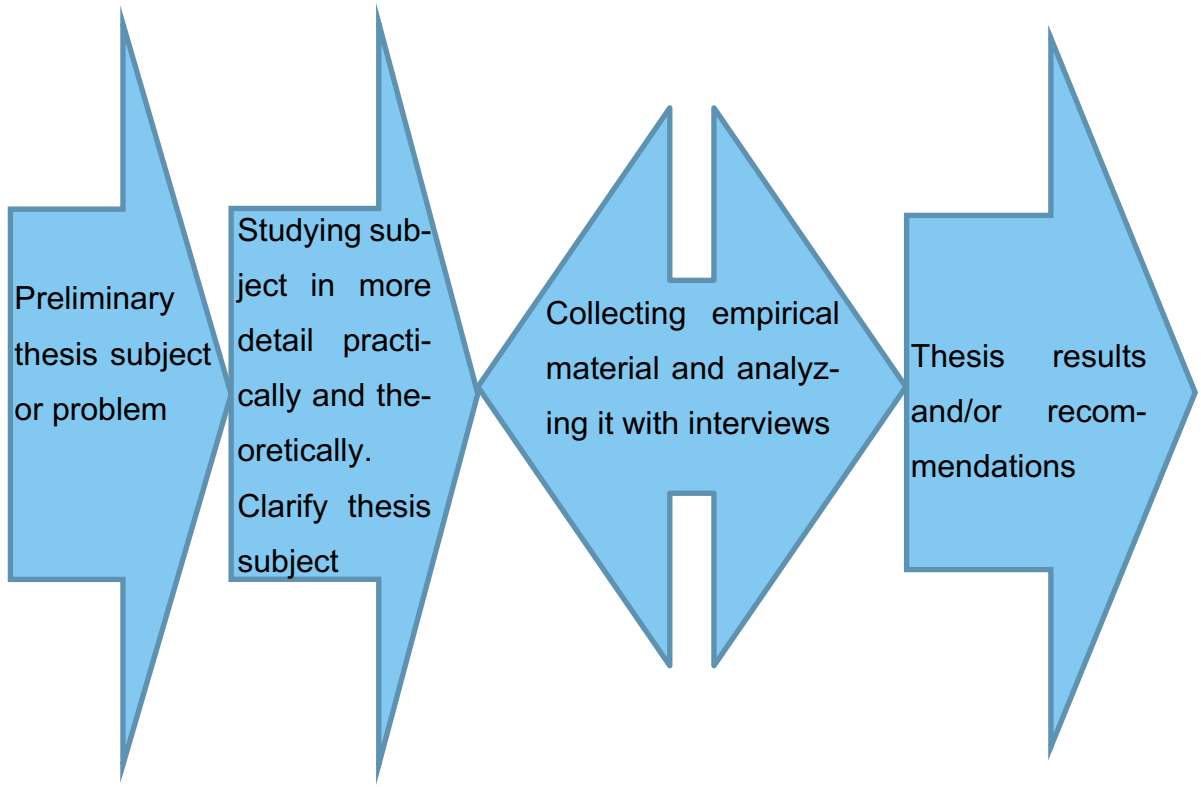

FIGURE 9. Case study steps (Ojasalo 2015, 54, modified)

5 RESULTS

In these next chapters are shown results and analysis from the Delfoy interviews. Delfoy interviews brought, like planned, a lot of information from the greenhouse projects and the problems faced, and this helped narrowing down the thesis subject and determining right questions in the questionnaire.

5.1 Delfoy Interview results from open and & theme questions

Delfoy interview started with one open question “What would be good questions to ask from persons which have already built or purchased a greenhouse in US” in here interviewees could bring their own ideas. This showed to be a good question before going into the theme questions.

As there can been seen from the table 3 that in their recent greenhouse project there are many topics which could have been done differently and better way. When looking at these topics what came up from the interviews there are all areas from the design phase to ramp-up production phase. This further confirms that there’s no well-established concept in the greenhouse project.

TABLE 3. Delfoy interview results from open and theme questions

Topic	**Open question**	**Theme question**
Project costs & budget	x	
Greenhouse concept	x	x
Greenhouse construction phase	x	x
Other greenhouse businesses	x	
Greenhouse design	x	x
Energy	x	
End product	x	x
Greenhouse layout	x	x
Customer responsibilities	x	x

Decision making	x	x
Greenhouse technique	x	x
Land zoning and permit process		x
Material logistics and deliveries		x
Contractors		x
Commissioning & production ramp-up		x
Project management		x
Suppliers		x

5.1.1 Result analysis

From the interviews came up topics and themes which will have big impact on a project and can easily ruin planned budget if things go wrong or these haven't been taken into the consideration in a design phase. Out of all the topics these topics had the most difficulties in the recent greenhouse project:

- Greenhouse design phase
- Material logistics and deliveries
- Project management
- Greenhouse concept
- Land zoning and permit process
- Greenhouse technique and applications

5.1.2 Greenhouse design phase

Almost 1/3 of all the problems in the recent greenhouse project were identified under greenhouse design phase. On the other hand, interviewees said that there was lot of planning and design but at the same time it was stated that, that didn't quite work out. Biggest themes from greenhouse design section are:

- Quality issues – greenhouse layout was unsuitable for Florida weather and for example gutters were too small for Florida summer rain

- The germination room was located directly underneath of offices and room started to mildew which caused health issues to the people
- Some parts of the greenhouse layout were already designed and decided – compromises should be always avoided in design but in this case, compromises were a must
- All the pieces in the greenhouse weren't properly connected – whole greenhouse with all pieces weren't in one layout
- When combining different applications, result is quite complex system – power supplies and location of cabinets, location of doors, people flow, product flow inside the greenhouse, etc.
- In US the imperial system is in use instead of metric system – All the parts came from Finland and EU where everything is designed in metric system and even when everything was converted to the imperial system it's complex especially for US contractors
- Good design and planning – all should be based on tested facts or concept
- Greenhouse should be designed in a way that it can be replicated – now there were many issues that this design can't be replicated

Design phase is maybe the most important phase and in that phase many things can be thought and handled before it costs too much. If things must be changed or modified in the construction phase, it's often much more expensive. But at the same time if you're building something this complex for a first time in many cases it's impossible to think all the pieces in the puzzle and have them connected properly in the design table.

5.1.3 Material logistics and deliveries

Material logistics and deliveries is a big part of project of this size. During project 50 containers arrived at the site and as well multiple smaller airfreight shipments. Handling all this material at the site needs good organizing. Themes from this section are:

- All containers were packed in Finland or EU and those were shipped to US – deliveries had estimated arrival times but those had a habit to

change. Also, it's difficult to determine right time for the shipment and installation since there wasn't space to store everything at once on the site

- One part is to unload the parts from container to the site and second part is how store them in a right way – unloading parts from container might take one workday for 4-5 people and how to store material in a proper way for example away from the sun or rain
- Different materials arrived at different times at the site – how to make sure that all the materials are received when shipping lists are missing, or information is partial. If for example bolts are missing from the shipment those are difficult to find in US (metric – imperial)
- How to prepare for the unexpected event – one container full of steel parts for the greenhouse structure lost during transportation and was never found

In conclusion, there needs to be a good plan on what to ship and when. On the other hand, project construction phase schedule needs to be followed so you don't end up in a situation that the material which is needed now arrives in two weeks, but you also want to avoid filling your site with too much material.

5.1.4 Project management

Project management is essential part of a project but especially in a greenhouse project, management is crucial. Building a complete greenhouse consists of so many different aspects which are needed to take into consideration. Like it's mentioned in the earlier chapters, greenhouse is like a factory where you have building, production, applications, people and so on. Following topics came up from the interviews:

- Project organization and especially project manager (PM) needs to have experience from construction site management – now project manager was inexperienced from the construction management which had effect for example on the quick decision making during the project
- When PM is doing this kind of project for the first time and background is not from construction you have no knowledge to tell how long certain job takes time or challenge the information what supplier or contractor is giving

- Contractors are quoting for this particular job for the first time – this makes difficult on scheduling the project and connecting all the jobs together in an efficient way
- Project schedule is extremely important, if you can't form and follow project schedule you end up losing money – in the latest project there wasn't sanctions for the contractors or suppliers if they fail to keep up with schedule which was given, and this caused domino effect where everything started to fall behind
- Project management – there must be someone from your own organization always present in the site so you can be sure that there is "your people" always supervising the project
- Decision making and simplicity – during the project decision making was sometimes too complex, due to lack of understanding on the constructional aspects in the project management but also a lack of communication inside the project organization

Experienced project organization and project manager has often a big effect on the project outcome. Of course, not everything can be fixed with good project management but often, it makes things easier.

5.1.5 Greenhouse concept

Greenhouse and concept words have come up multiple times in the previous chapters and title of this thesis focuses on connecting those words together. Interviewees tried to give answer on what do they think that the "greenhouse concept" should include. It's kind of easy to say that there is a need to establish concept in the greenhouse but what it really should include? Interviewees saw that following things should be included in the greenhouse concept:

- Big picture – in the last greenhouse project there wasn't a clear picture on the finished outcome of the project. Of course, there were layouts and drawings but there was not one big layout where everything was added and connected. For example, there was a plan to use rainwater as a part of plants irrigation water. Rainwater collection tank was drawn in the other layout and irrigation tank in another but there wasn't a plan how to build

working system to pump water from the collection tank to the irrigation tank.

- Greenhouse concept should include many more aspects than just building and growing tables – it should also include aspects for example:

    - It's a greenhouse but also a plant factory
    - How greenhouse works (all functions inside and outside green-house)
    - How it is built (in a detailed way)
    - How it is operated
    - People management
    - Plan how to sell and do marketing for the product – Once green-house concept is decided, and growing environment is built you can't grow anything you like in the greenhouse. Greenhouse has limitations, for example you can't grow tomatoes in the greenhouse which is designed for growing herbs

It's also mentioned in the previous chapters that greenhouse business is a new business area. Compared this for example common house construction which has been done more than 100 years there is the concept that is being repeated continuously.

5.1.6 Land zoning and permit process

The greenhouse in Southwest Florida was first of its kind. This created scenario that there was no clear picture what is needed from the land zoning and what kind of permits are needed to be able to build a greenhouse in the land which have been purchased. Also, it didn't help that not even local authorities didn't know how to handle this kind of building permit application. Main topics that came up in the interviews:

- No clear picture – what can be build and how and how the greenhouse needs to be placed on the land

- What kind of environmental permits are needed – permit process took almost as long as construction phase (1.5 years) because there was lack of knowledge in the project management but also in the local authorities
- Permit process with local engineering office – no knowledge from the greenhouses in local engineering office

Somehow, it's understandable that if you're building something for the first time that the land zoning and permit process takes time. Still, 1.5 years is a long time before you can start any kind of land work and only after that the construction work can begin. During this permit process there was a discussion whether the greenhouse is an agricultural site or industrial production site. In the end it was determined by the local authorities that it is an agricultural site and that lowered the demands in the greenhouse, for example there was no need for sprinkler system inside the greenhouse, handheld fire extinguishers were enough.

5.1.7 Greenhouse technique and applications

When selecting the greenhouse technique and applications, whether it's a cooling or heating system, climate operating system or growing technique there should always be used techniques and applications which are tested, and it's proven that those techniques work in a big, greenhouse scale. From the interviews came up following topics regarding the greenhouse technique:

- New technique and applications – cooling system was a first of its kind in the world in this scale. Cooling system had 3 x 50m^3 water tanks which were buried under ground. Tanks were made from fiberglass and during production ramp-up there was a crack found in the fiberglass which caused delay in the ramp-up because all the tanks had to be emptied to be able to fix the crack
- Cooling system chiller malfunction – in case there is a malfunction in the chillers, like there was during production ramp-up that causes rapidly major problems. In Florida weather if cooling system is out of order for more than 12 hours all the production is most likely lost because the temperature raises too high inside the greenhouse. Greenhouse was also fully closed so it didn't have any ventilation or hatches which meant that there was no

possibility to exchange air or ventilate the greenhouse if the cooling system was out of order

Technique is an important part of the greenhouse operation and these issues which were in the latest project moved focus from the production and in this case these problems disrupted production ramp-up many times.

5.1.8 Other findings from Delfoy interviews

Other topics that came up from the interview were:

- Greenhouse construction phase – lack of big picture and knowledge from construction project made difficult to determine what is needed to do and in which order
- Commissioning and production ramp-up – you need to have a good plan to ramp-up the production and that shouldn't take too much time. Like mentioned in the previous chapters new techniques and applications such as cooling system took too much focus from the successful ramp-up
- Contractors – workers might not know how to read metric system or how to use metric measuring tape. There were also unclear contractor agreement limits which resulted in the grey areas between agreements
- End product – there needs to be a clear picture and good understanding from the end product and design of the greenhouse so it matches the best way end product needs
- Customer responsibilities – in the contract's suppliers included many responsibilities for the customer such as power supply, water supply, compressed air supply and location of drains in the building. However, suppliers could have provided better information for example how much water do the machines or applications use and how much water they let out to the drain system

5.2 Questionnaire results and analysis

Questionnaire was sent to the people who have been building greenhouses in the US and were the target audience. Questionnaire had also ready-made answers so that the results could be compared but there were also couple of open questions where more info could be given. These questions and ready-made answers can be found from appendix 4. This questionnaire was sent to 35 persons and 8 answers was received which gives 23 % as a response rate. Every person who took this questionnaire presented different company which improves the results.

Persons who answered to the questionnaire worked in different roles, like it can be seen from the figure 10. Biggest group was head grower or grower. Some of them had multiple roles in the project which tells that project organizations are often small if there even is a project organization and one person answered that he held all the roles.

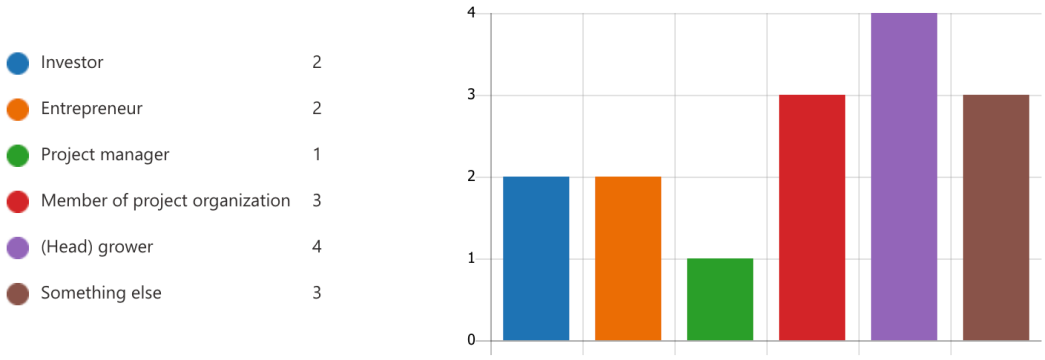

FIGURE 10. Person's role in the greenhouse project

5.2.1 Greenhouse design phase

In the questionnaire there wasn't one direct question related to the design phase but still there can be seen that something could have been done better in the design phase since all the questionnaire respondents wanted to change something from the greenhouse after it was finished. Maybe some of these could have been solved already in the design phase. For example, 2 of the respondents

would like to change layout in the greenhouse and same goes with the seeding machine, like it can be seen in the figure 11 and 1 hoped better design on the peat removal system in the “something else”. In conclusion 5 out 8 persons would like to change something.

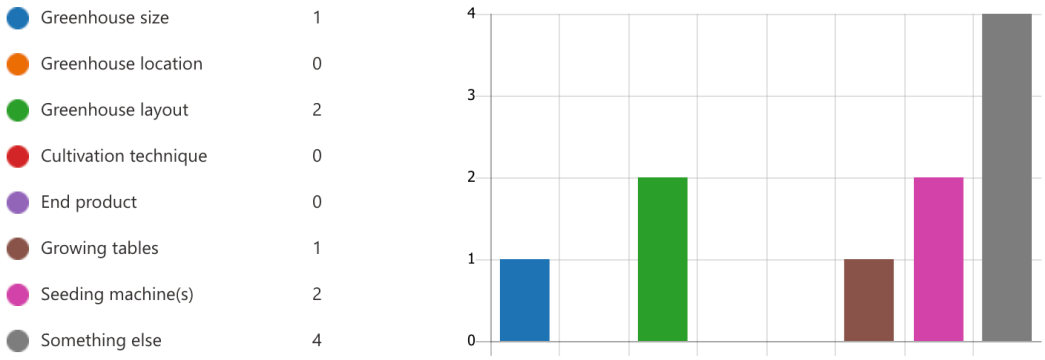

FIGURE 11. What changes persons would like to do for the operational greenhouse

In addition, when asked “how well greenhouse layout matched your operational needs” 1 person said “neutral”, and 2 persons said “somewhat not well” as it can be seen from figure 12.

FIGURE 12. Answers from the questions “How well greenhouse layout matched your operational needs”

5 out of 8 people answered to the questions “How well you were able to combine cultivation technique with building” that it was somehow difficult, and modifications were needed during machine and technique installation as it can be seen from figure 13.

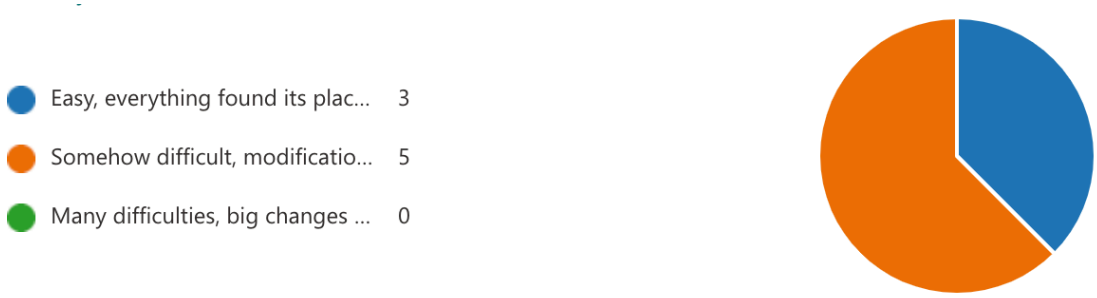

FIGURE 13. Answers from the questions “How well you were able to combine cultivation technique with building”

All these answers confirm the importance of the design phase. That is the phase where project organization should invest time because if you can sort out for example layout issues in the design phase, most of the times it costs much less than after the greenhouse is finished and in operation. When said that design phase can save costs 4 out 8 respondents answered that project went over the budget more than 20 %. For sure, Covid-19 had impact on the cost side with delays and part shortages but maybe some of unexpected costs could have been avoided with more detailed design.

5.2.2 Material logistics and deliveries

Material logistics and deliveries is a big part of greenhouse project. In Southwest Florida greenhouse project around 50 containers were shipped from Finland to the US. There were problems in the Southwest Florida project with logistics and there have been similar problems with other greenhouse projects as well. As it can be seen from the figure 14, 6 out of 8 persons answered that they had problems with this.

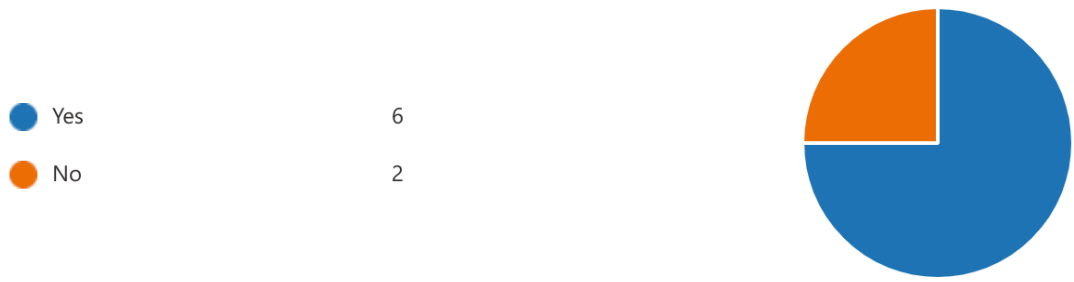

FIGURE 14. Results from question “did you have any problems in the material logistics or deliveries during the project”

The similarities with problems other greenhouse projects had, are noticeable. It’s not a surprise that materials came in containers to the US from Finland and EU but there were also problems that the deliveries were late, and materials were lying on the site in unsuitable conditions for example not covered from the rain. Summary from the problems with logistics and deliveries can be seen in figure 15.

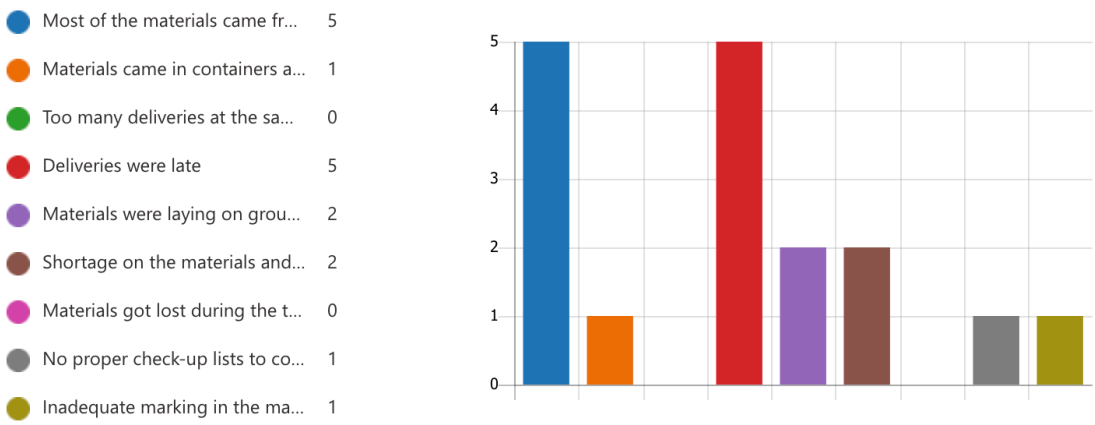

FIGURE 15. Summary of the problems in the logistics and deliveries

Some of the issues were related to Covid-19 and global pandemic is something which cannot be avoided but couple of the answers stated that there was no proper check-up lists and markings on the parts were inadequate. These are problems which supplier could fix easily since for example all the information what is shipped from supplier warehouse must be available. In all, even without Covid-19 there is room to improve in the logistics and deliveries subject.

5.2.3 Commissioning and production ramp-up

Commissioning and production ramp-up is important phase when operation of the greenhouse is about to start. In the Southwest Florida project there were major difficulties with production ramp-up because of the issues with different systems, mostly with cooling system. There seems be issues with this subject also in the other greenhouse projects. It can be seen in the figure 16 that 4 out 8 people said that they had “some” or “major” issues with production ramp-up.

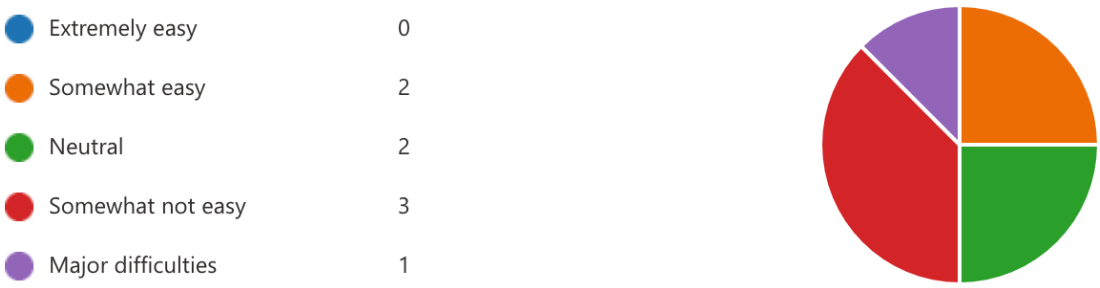

FIGURE 16. results from question “How would you rate the success of production ramp-up”

When asked more information what kind of issues there were in the production ramp-up this kind of answers were given:

- “Lot of things broke, and it was difficult because this happened during Covid-19”
- “Not easy to ramp-up when demand is not fully known”
- “Industry is new, and systems required modification”

Many of these findings came up also in the Delfoy interview and this confirms that, yes industry is new and production ramp-up can be a big challenge. In all, these problems are still something that can be, if not fully avoided, but at least thought in advance and good plans can must be applied.

Commissioning of the machines and applications can be done better from the supplier side. According to the answers from questions “During greenhouse commissioning did you get enough help from the suppliers” 3 out of 8 people said that

they didn't get enough support from suppliers. And when asked what suppliers could have done better, following comments were given:

- "More clear maintenance and setup instruction"
- "Still not commissioned"

Commissioning part was incomplete also in Southwest project. This is something that customer needs to demand from the suppliers and suppliers should be well prepared to execute commissioning for all the machines and applications and more importantly provide sufficient documentation from the commissioning. Commissioning should be approved by both parties (customer & supplier) and only after this customer could start safely operating the greenhouse.

5.2.4 Land zoning and permits

In the delfoy interview came up that in Southwest Florida project land zoning and permits caused major problems and delay in the project. However, according to answers from questionnaire this was an issue only 1 out 8 projects. But the issue which one project had, had big issues and assumable caused big delays in the expected project schedule. When asked more details about the issues project had with land zoning and permits the answer was following:

> *Many problems, first the county building inspector verified the building but then he was not qualified, so the permit was pulled, then the engineered drawings from the manufacturer were not good enough so had to hire a local structural engineer to verify the engineered drawings, and then the state would not accept those drawings without another engineer verify the first engineer and the engineered drawings.*

So, even though problem was only in one the projects the problem which faced seemed to be big and this is something that needs to be addressed in the beginning of the project, so it won't ruin project schedule immediately in the first steps.

5.2.5 Project management

Project management can make a big difference on either way, whether is going well or not so well. According to questionnaire 7 out of 8 persons answered that they had external partner or company which oversaw the greenhouse construction phase. But when was asked “Would you have needed an external partner or company to help you go through a greenhouse project from start to finish”, only 3 out of 8 said that they would have needed external partner, as it can be seen in figure 17.

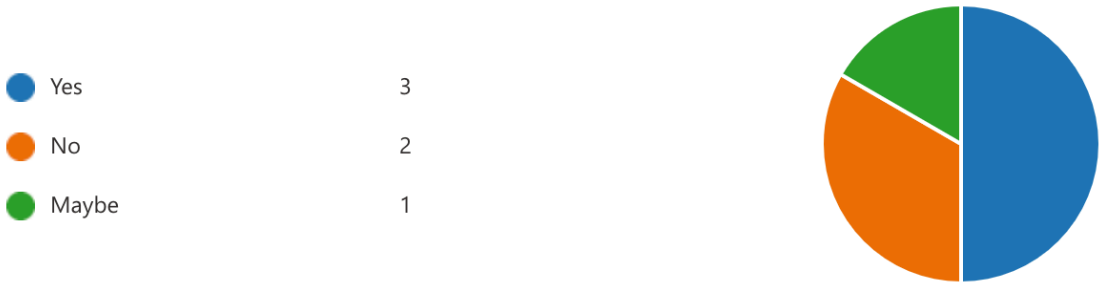

FIGURE 17. Results from question “Would you have needed an external partner or company to help you go through a greenhouse project from start to finish”

Of course, the number of answers is limited but it still gives guidelines that entrepreneur, project manager or project organization sees that they can manage the whole project without external expertise.

5.2.6 Most challenging parts in the greenhouse project

One of the questions was where persons could give points to the project phase depending on how demanding it was. Phases which to give points were:

- Material logistics and deliveries
- Greenhouse commissioning and production ramp-up
- Greenhouse construction phase
- Taking care of water and power supply for the building and machines
- Project management
- Greenhouse design phase

Points were given in the following way:

- 7 = extremely challenging
- 6 = challenging
- 5 = somewhat challenging
- 4 = neutral
- 3 = somewhat easy
- 2 = easy
- 1 = extremely easy

It has been already mentioned in the greenhouse commissioning and ramp-up chapter that, that phase in the project can be challenging and according to figure 18 highest points were given to this phase of the project.

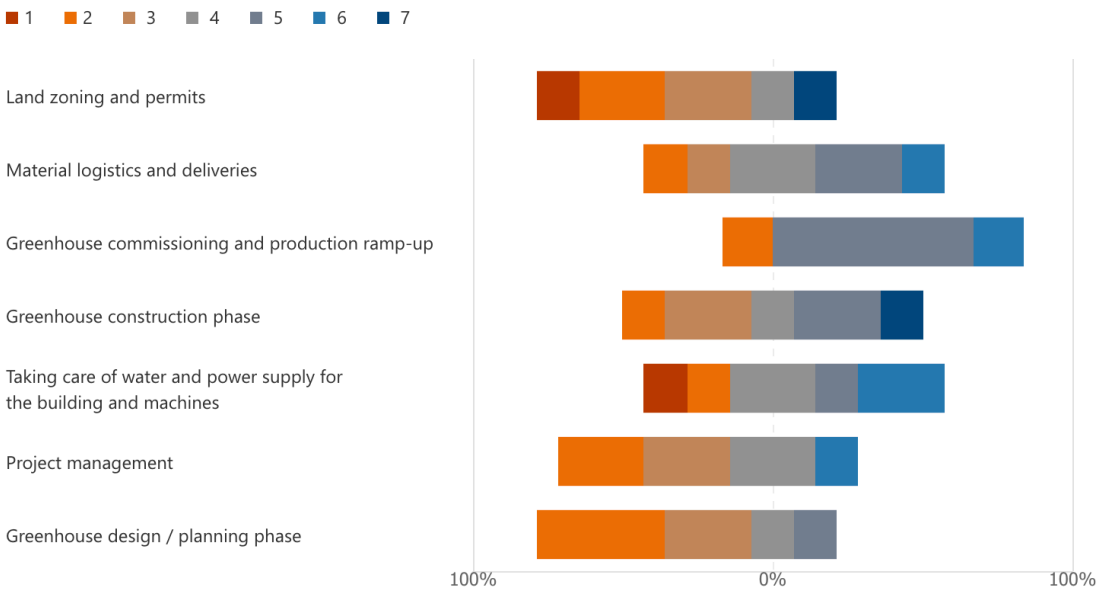

FIGURE 18. Project phase scoring

5.2.7 Summary

6 out of 8 people gave 5 points or higher to the “commissioning and production ramp-up” phase so clearly that phase has been challenging. Tie for the second challenging was “material logistics and deliveries” with “taking care of water and

power supply for the building and machines”. All these phases caused problems also in the Southwest Florida project.

Easiest phase seemed to be “land zoning and permits” except like mentioned before one of the projects had major issues with this and most likely score from that project is 7 = extremely challenging, and second easiest phase was “green-house design phase.” However, even that the design phase seemed to be one of the easiest phases in that phase some of the changes in the greenhouse layout could have been avoided, since couple of respondents would have liked to change things in the layout.

In conclusion, even when there’s only 8 persons who took the questionnaire all the answers had good quality and open question explanations gave great value on the subject.

6 FINNISH GREENHOUSE CONCEPT HANDBOOK

As a result of this thesis is a handbook for Finnish hydroponic greenhouse concept to the US market. This handbook is focusing on making better greenhouse projects in the future and concentrates on the subjects which was brought up from the delfoy interviews and from the questionnaire answers. The handbook gives guidelines and instructions on how for example land zoning and permits could be done differently and better way in the future projects. Topics that this handbook will cover were the most problematic in the past greenhouse projects:

- Material logistics and deliveries
- Commissioning
- Production ramp-up
- Greenhouse design & customer responsibilities
- Land zoning and permits

6.1 Material logistics and deliveries

Material logistics and deliveries were the phase which greenhouse projects had many difficulties and problems. It's not easy to handle material logistics in the "normal time" but when you add global pandemic into the equation it's certainly not making things any easier.

Like mentioned before all the materials in the Finnish greenhouse project comes either from Finland or from EU area. For example, in the Southwest Florida project 50 containers arrived at the site during project. In summary, problems according to the questionnaire answers were:

- Most of the materials came in containers from Finland & EU
- Deliveries were late
- Materials were laying on the ground in wrong conditions and they were in wrong place
- Shortage on the materials and urgent airfreight were needed to use
- No proper check-up lists to confirm that all the materials are received

- Inadequate markings in the received materials

First of the problems is maybe not a problem but more a fact that materials will be delivered in containers from Finland and EU area and that is something that is needed to cope with. With good planning this problem can be reduced as small as possible. There are still multiple actions that can be done to improve material logistics and deliveries.

When planning the material delivery to the project site most likely the land for the greenhouse is already acquired. All the information regarding the conditions of the land is also well known. These following steps should be followed when planning the deliveries:

1. Study a possibility to fit approximately 50 containers in the greenhouse project site at the same time.

If answer is yes, all the containers that are going to be used for transporting materials should be bought. Why buy containers which costs ca. 5000€ / unit? When all the containers are owned, they can be all put on the site and materials can be kept there during the construction and unload materials when needed. This way materials are kept safe from the weather and once the containers are placed in the right place in the beginning of the project these doesn't have to be moved. Also, additional, and unnecessary material moving around the construction site during the project can be avoided.

After project is done and if there's a need to store any materials outside of the greenhouse these containers can be used, and additional containers can be sold. Investment of 50 containers seems big but there are benefits with owning the containers and some of the invested money is returned when selling the containers. In addition, all the materials can be shipped at once and after the containers are placed in the right place shipments can be inspected without rush. This should also prevent delays in the shipments and expensive airfreight shipments.

However, if the answer is no and there's no room for all the containers at the same time on the project site or containers can't be bought there is still steps that can be done to improve material logistics.

2. Project schedule and good planning on the material shipments

When the greenhouse design phase is ready, and layout of the new greenhouse is ready, bill of materials follows soon. Together with suppliers there should be planning meetings where all the material shipments are scheduled. Of course, over the sea shipments has uncertainties and shipment schedules might move back and forth but still having detailed plan for shipments are recommended and important to have. Shipments should follow project schedule but because shipments have uncertainties + 3-4 weeks is good to have as a buffer in the shipments.

3. Marked locations for the shipments on the project site

All the materials should have own marked locations and this information should be found from the project plan and be available for everyone who is working at the site. For example, if all the structure parts of the greenhouse have one specific place this helps finding the parts and inventory of the parts is easier. Location should be clearly marked for example:

- A is for structure parts
- B is for wall elements
- C is for growing tables
- Etc.

To make this work all the parts which are arriving to the site needs to have a proper and understandable marking on it. Without proper markings it's impossible to know what part goes in which location. In addition, the persons who are on the site and are receiving shipments needs to have a proper shipping list from each container which is being unloaded to the project site. This way materials can be effectively sorted in the right locations.

4. Nominated persons to receive and sign shipments

On the greenhouse project site there should be only couple of persons who can receive shipments and sign shipment papers. These persons should be familiar on the materials which are coming and if markings on the shipments or parts are inadequate, they should have access on the 3D drawings where they can easily check the part name and purpose.

5. One marked location for urgent shipments and courier deliveries

In the project site there are urgent deliveries, even when the planning has been good. These urgent shipments are, like name says, very often urgent and needed at the site immediately and many times these shipments are small boxes and is delivered by courier. That's why these shipments should have special place marked with big sign so all the couriers can see it immediately when they arrive to the project site. Same policy should be with these shipments that only nominated persons should receive and sign shipments since this helps keeping track of the shipments.

6. Prepare site infra in advance

One valuable finding from delfoy interview was that since Southwest Florida site infra and courtyard areas weren't prepared before construction work started and during the project there is lot of traffic from cars, trucks, and work machines. Especially in the summer when it rained heavily and big ponds emerged here and there in the project site this caused damage to some of the materials. Whole project site land was fine sand which didn't allow rainwater to go through easily, but if all the areas would have been for example prepared with gravel or asphalt, the situation would have been much better. All this would have helped material logistics in the project site.

6.2 Commissioning

This phase of the greenhouse project had most challenges. Commissioning of the machines and applications is important since only after successful commissioning customer should start operating the greenhouse and start production ramp-up. Supplier of the machines is responsible for commissioning, and this is something that customer needs to demand from supplier. How to improve commissioning.

1. Commissioning and the criterion for acceptance written in the contract between customer and supplier

To be able to have a successful commissioning this phase needs to address already in the contract negotiation phase and to be written in the contract. Commissioning can be also joint operation between customer and supplier. If customer representative, for example person who is responsible for maintenance is already known, it's good to have this person involved in the commissioning. This way that person learns and gets valuable information from the machines and applications that are in the greenhouse.

2. Commissioning paperwork and acceptance

Many times, it's the case that even the commissioning of the machines and applications is done partially and especially the close-out phase is often neglected. In the close-out phase supplier should provide all the paperwork from systems, machines, and applications that those have met its acceptance criteria. If this paperwork is not done and provided from the supplier, customer should have right to say that machine or application is not properly handed over to the customer and therefore for example warranty period cannot begin. Warranty period should start only after a successful commissioning and paperwork.

6.3 Production ramp-up

Production ramp-up is often complicated and time-consuming process and to the people in the greenhouse it is most likely the first time when they are doing this.

In the questionnaire when was asked if they had greenhouse and then customers or customers then greenhouse, 7 out 8 people answered that they had greenhouse first and then the customers. This means that there is no immediate demand on the production and products, but still production needs to begin, and most likely possible future customers likes to see samples before committing to buy production.

Easiest of course is that if there's already a customer, then production ramp-up has a clear direction. Still, it doesn't matter if there are customers or not there are things that should be taken into consideration when planning production ramp-up.

1. Purchase critical spare parts in stock already in the project delivery to prevent distractions in the ramp-up phase

Supplier should provide a list where is listed what parts are critical in their application, but if not, customer should ask the supplier to provide this list. It's a big benefit if critical parts are already in stock and something breaks down in the production ramp-up. Especially, when almost all the parts come from Finland a that alone generates delay to have new part immediately to the greenhouse and 1 week is almost a minimum time what it takes to have new part from Finland to US.

2. If there are new innovations and applications in the greenhouse put these extra attention

If the greenhouse has some new innovations and applications and especially if these are installed for the first in the scale of a greenhouse, make sure that you put extra attention to these applications. It's not new that new innovations don't start working like a charm straight from the beginning. These applications should be commissioned first if that is in any way possible.

3. Make sure that the commissioning is done on the whole greenhouse before starting the production ramp-up

Like mentioned production ramp-up is often difficult process, it takes time and the last thing you want during the ramp-up that some machine brakes down and causes delay in the ramp-up. However, these break downs can still happen, but if all the machines and the whole greenhouse is commissioned in a proper way the possibility to have break downs should be significantly lower.

4. Plan the production ramp-up at least in a way that the output is minimum of 20-25% of full capacity and pilot the output of production with 100% and be prepared for the costs from scrapped production. Test everything and all the scenarios you possibly can.

Why produce something if there's no customers? Greenhouse production cycle depends on the species what is grown but for example for basil it takes approx. 35 days to grow from seed to full grown plant. Greenhouse in many cases is a unique system and it takes time to learn how its "acts" in different circumstances. It's hard to tell with 100% accuracy what is for example CO_2 level inside the greenhouse before it's full of growing plants. This means that it takes time to learn how greenhouse works. Also, there are many things that needs adjustments in the beginning:

- Growing tables
    - Movements and fine tuning
- Climate control
    - Humidity, temperature, and sunlight exposure
- Real growing and production cycle
    - for example, for basil the growing time can be different in different greenhouses, even if it's one day it makes great difference in one year
- Flow of products and all the functions such as packing needs to be practiced
- Automation system needs adjustment in the beginning
- Irrigation system
    - Optimizing the fertilizer levels
    - Optimizing the interval between the irrigations and water quantity

- Different species experiment
    - For example, which basil specie is the best in this specific greenhouse
- Etc.

Even if it's seeming a bit unwise to produce and then throw that production to waste this is the only way to learn the lessons from the greenhouse cultivation. It might take several months before greenhouse is fully known how it behaves and produces and to fully understand everything what is happening in the cultivation and what effects on what, it most likely takes more than a year.

6.4 Greenhouse design phase & customer responsibilities

According to the questionnaire results on which phase was the most challenging one greenhouse design showed to be one easiest phase in the whole project. However, the results also said that customer responsibilities, need for modifications to the layout afterwards, and combining cultivation with technique had problems in the projects and some of these issues could have been avoided with if greenhouse design would have done differently.

1. Invest time on the design phase & planning, it most likely pays itself back

If more time is invested in the design phase many times the possible problems in the future can be solved before project reaches to the construction phase. Still, it's good to keep in mind that size of a project like greenhouse is, it's impossible to think all the scenarios and think about all the possible problems that can occur.

Suppliers level of design should be detailed and give all the information what is necessary for example if customer needs to design location and size of the drains to the greenhouse, then supplier needs to provide information on where water is used in their application and how much water goes to waste. In addition, the more detailed design, easier it makes negotiating contractor agreements and determining the expected cost for the project budget. This phase should also include business planning not just greenhouse design and planning. Business planning is as important as designing properly working greenhouse.

2. As a customer collect as early as possible all the information from suppliers from machines, applications the requirements for power, water, and air supply design

If customer is responsible for providing general power, air and water to the machines and applications, customer needs to be alert and collect all the data from this area. Only with proper information there can be right kind of design for example to the general power supply and electrical cabinet amount, size, and number of outlets in them. At least in the Southwest Florida project after the project was done there was a need to have additional power supply but because design was done partially all the cabinets were full and there were no spare outlets. This caused delay since to be able to have additional power supply, completely new cabinet and cabling was needed.

3. One master layout with all the information

Desired situation should be always that even if in the project there are multiple suppliers there should be one master layout where all the information is combined. Only this way it's possible to check all the aspects in the project and make sure that everything is connected properly together. Suppliers rarely like to share their information with other suppliers so it might be difficult to combine all the information especially close to the contract delivery limits but there can be for example 3rd party which collects all the data and drawings and combines them into one layout.

6.5 Land zoning and permits

Only 1 out of 8 projects had problems with land zoning and permits along with Southwest Florida project this subject is so important part of the greenhouse project that this is something that needs to have a good action plan so hopefully all those issues can be avoided. If something goes wrong in this phase of the project, it most likely has dramatic consequences for the project and its planned schedule.

As an improvement plan for future project there was an additional discussion with the person who oversaw Southwest Florida greenhouse project. As a result, from this discussion, it's possible to form an action plan on what aspects needs to be taken into consideration in the greenhouse project in the land zoning and permit phase.

There are multiple topics under the land zoning and permits phase and those topics can be divided in the following way:

- Zoning
- Environmental
- Geotechnical
- Water management
- Potable water
- Wastewater
- Groundwater
- Transportation
- Permitting
- Legal
- Site development costs
- Structural

6.5.1 Zoning

In the zoning topic things that should be clarified.

1. Fully covering plan of land use
    a. Review the comprehensive plan to ensure that the proposed use of land (greenhouse) is allowable under the municipality's comprehensive land use plan
2. Zoning
    a. Check that the existing zoning to confirm that agriculture is an allowable use

   b. Check that the proposed development plan meets the zoning requirements including possible setbacks, parking requirements, architectural controls, hours of operation, maximum building height, native vegetation, preservation requirements and required landscape buffers
3. Overlay districts
   a. Review the local regulations to determine if the proposed property for the greenhouse is subject to any overlay districts that may prohibit or encourage the proposed land use

6.5.2 Environmental

In the environmental topic things that should be clarified.

1. Environmental sensitive vegetation
   a. Review US geological survey (USGS) soil maps to check soils to if the proposed area for the greenhouse has environmentally sensitive vegetation
   b. Contract with local environmental engineer to conduct a site inspection to determine if there are any protected species under local, state, or federal protection
   c. Identify and quantify possibly species that are protected, threatened, or have special concern that may be under a threat or have impact the habitat in the proposed greenhouse land
   d. Carry-out analysis part I to determine if there are any potential chemical contaminants on the proposed land that would require actions before moving forward
   e. Carry-out analysis part II if the part I report indicates that a more detailed analysis is required

6.5.3 Geotechnical

In the geotechnical topic things that should be clarified.

1. Review USGS maps to determine if proposed land for the greenhouse have sufficient durability to support the proposed structure without any site-specific improvements. If improvements are needed further inspections might be needed to avoid big surprises on the costs
2. Define if the area is proximity to limestone that it may be subject to sinkhole formations that might require further preventive actions to minimize risk of sinkhole development potential
3. Identify penetration rates for the typical soils if needed for stormwater analysis

6.5.4 Water management

In the water management topic things that should be clarified.

1. Flood plan
    a. check data or other available topographic data resources to determine if the proposed land for the greenhouse is in possible flood area and if it will require any compensating flood storage
2. Water quality
    a. Identify the water quality requirements from the local jurisdiction and inspect the proposed land to determine if it meets the criteria
3. Stormwater outfall and discharge rate
    a. Identify the stormwater quantities and the building structure so that it will meet the criteria
4. Identify the minimum finish floor elevation (FFE) for the structure and determine the fill volume required to raise the site to meet the FFE minimums
5. Check if the proposed site for the greenhouse is located within the limits of an existing permitted stormwater management system. If yes, check that the proposed site plan meets its criteria

6.5.5 Potable water

In the potable water topic things that should be clarified.

1. Check if the proposed location is inside the public or private potable water utility
2. Check the source of potable water and carry-out chemical analysis of the water to determine if there are any pretreatment requirements before it can be used as irrigation water.
3. Prepare a preliminary design and cost estimate to extend potable water feedline to the site if not existing already

6.5.6 Wastewater

In the wastewater topic things that should be clarified.

1. Check if the proposed location is inside the public or private wastewater utility
2. Check that wastewater infrastructure is capable to handle the wastewater volumes from the proposed project
3. Prepare a preliminary design and cost estimate to extend wastewater feedline to the site if not existing already

6.5.7 Groundwater

In the groundwater topic things that should be clarified.

1. Check if the proposed location is inside of any water franchise area
2. Identify the aquifer that may be the source of the water project
3. Check the source of groundwater and carry-out chemical analysis of the water to determine if there are any pretreatment requirements before it can be used as irrigation water

6.5.8 Transportation

In the transportation topic things that should be clarified.

1. Check and confirm that prosed greenhouse location has legal access to a public Road of the way (ROW) or has legal access to any private roads that connect to the public roadway network
2. Check and review with local regulatory authority to determine if local road network has capacity for estimated trips to the greenhouse and back without any additional improvements
    a. If any additional requirements are necessary, quantify the related expenses

6.5.9 Permitting

In the permitting topic things that should be clarified.

1. Check and confirm all local, state, and federal permits that may require to construct the proposed greenhouse
2. Check and identify any possible critical paths, duration, and cost in the permitting process
3. Book a pre-application meeting with local water management district and municipal permitting authorities to confirm all the findings from step 1 and 2 and identify any requirements that may have been forgot
4. Check and verify with building departments and growth management departments of the local regulatory agencies that proposed use of land meets the agricultural use criteria which would qualify the project for certain permitting or tax exemptions

6.5.10 Legal

In the legal topic things that should be clarified.

1. Secure and ownership and constraint report to identify any easements, existing commitments or outstanding obligations related to the property
2. Verify that there are no mineral rights that would need to be taken care of

6.5.11 Site development costs

In the site development costs topic things that should be clarified.

1. Prepare a site plan that describes the proposed greenhouse structure and the required infrastructure improvements
2. Prepare an ‘Opinion of probable’ cost to determine the costs to construct the proposed site improvements

6.5.12 Structural

In the structural topic things that should be clarified

1. Determine the wind load criteria for the projected greenhouse location
2. Identify any possible improvements that may be required for the structure to meet the requirements if the wind load is high in the projected location
3. Quantify expenses from the improvements to the structure if any

6.5.13 Other

In addition, there is at least one factor that is good to go through before acquiring the land for the greenhouse and that is:

- Workforce availability
    - It’s good to think about the location also from the workforce aspect. Depending on the size and level of automation in the greenhouse there can be up to 20-30 people working, even more if harvesting is done manually. So, if the greenhouse is going to be built in the middle of nowhere it might be difficult to find workforce to the green-house

7 CONCLUSIONS

First idea of this thesis was to create an established concept for the complete greenhouse project. This result was partially achieved since not all the aspects wasn't processed in this thesis for example greenhouse layout using modularization is not processed in this thesis. Further the thesis work went the clearer it was that creating full concept for "Finnish hydroponic greenhouse concept to the US market" in one thesis is too big task and that the subject had to be narrowed down. As a result of this thesis is a handbook where many issues from the past greenhouse projects were addressed and, in the handbook, there is a detailed plans on how to do things better in the future.

First, using delfoy interview and interviewing two persons who has demonstrated history from greenhouse projects helped narrowing the subject of the thesis and from the results of the interview questionnaire was formed. This questionnaire was sent to the people who have already done greenhouse projects in the US. questionnaire was sent to 35 people and response was received from 8 people which gives 23% as a response rate. Number of respondents could be higher but all the persons who answered the questionnaire represented different companies and projects and the quality of the answers were high.

During the making of this thesis, it was found out that there are very few literatures existing which are written about greenhouses. Especially from subject "greenhouse project" there was not found known literature. This meant that all the information was needed to combine from the common construction project literature and greenhouse literature and this literature was telling more about cultivation and not on how to build and manage a modern greenhouse project. Even though that the outcome of the thesis wasn't a full concept for the Finnish hydroponic greenhouse the result of this thesis was success.

From the questionnaire there was much information received from the past greenhouse projects and this is beneficial when planning for future greenhouse projects. Using a qualitative research method showed to be right research method when thinking about this thesis subject. The answers on the questionnaire are

based on facts from real projects. This is something that literature can't tell that what are the subjects or phases in the greenhouse project that had problems. After those problems have been discovered there can be recommendations and action plans on how to do them better in the future greenhouse projects and this handbook gives recommendations and action plans.

7.1 Future research areas

This thesis focused on finding things to improve in the greenhouse projects in the US by collecting information from past projects. Like mentioned, as a result became a handbook from selected areas where most of the issues were, according to the questionnaire and delfoy interviews. The future next step research could be a study how to make concept to the greenhouse project complete. This thesis and handbook have parts of it already, for example to land zoning and permits and material logistics and deliveries but next research should be focusing on the greenhouse layout, construction and how to utilize modularization methods better way.

In the first chapters is mentioned that Finn Growers have done a pre-study that greenhouse could have 3 different sizes 1,3 and 5 hectare from which together with customer best option will be selected. Research could also focus on these 3 different size greenhouses and on design in a detailed way that what parts of the greenhouse could be always the same and this way modular. This means that next research should include more designing and 3D-modeling to the layout.

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APPENDIX

Appendix 1. Delfoy interview questions

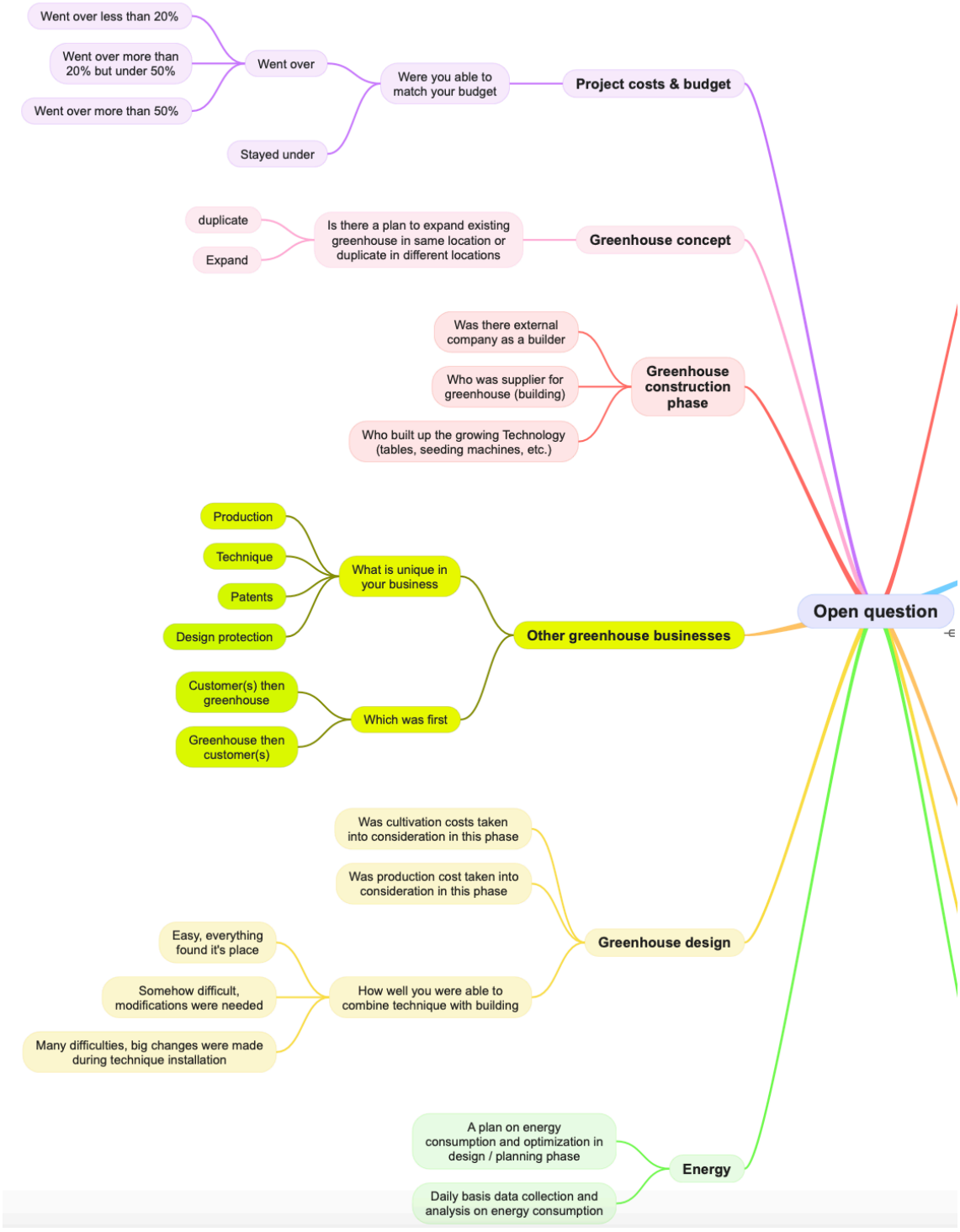
Open theme question:

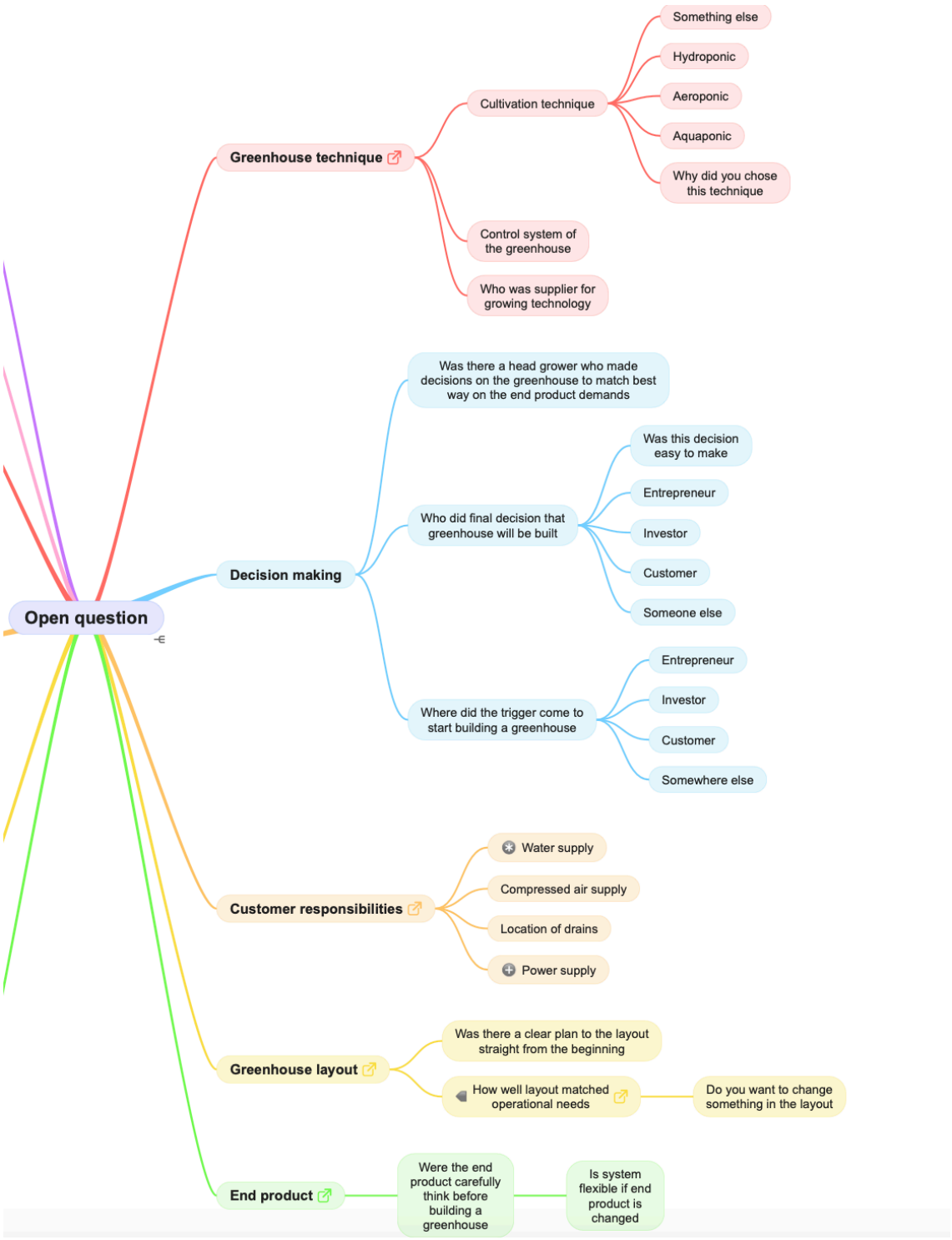
- What could be good questions to ask from persons which have already built or purchased a greenhouse in US?

Theme questions:

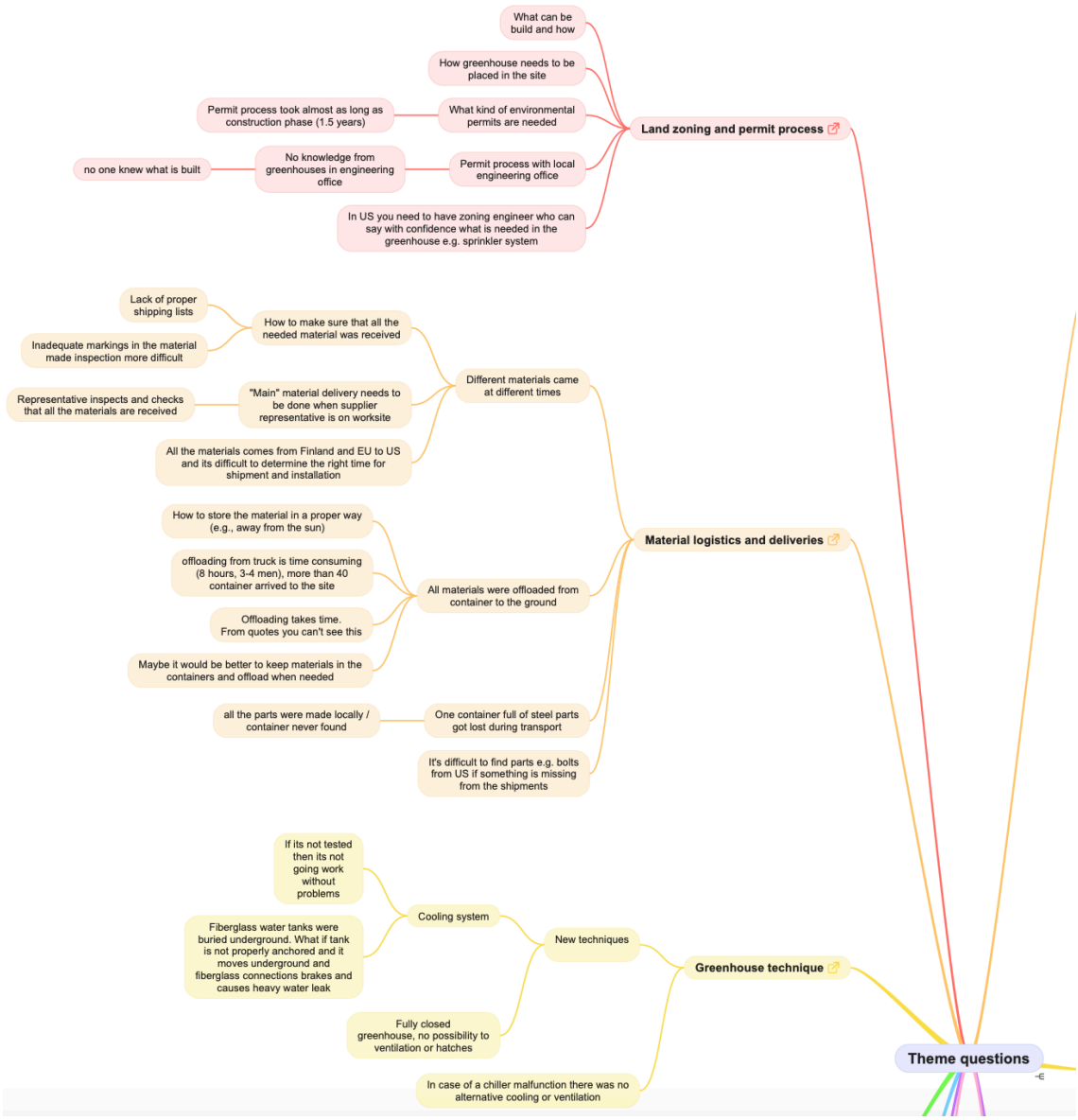
- Can you identify what has been biggest challenges when building the greenhouse in US? Especially when looking a complete concept from scratch to finish
- In your own words what do you think word “concept” means in the greenhouse project? What it consists of?
- How would describe level of design and engineering (e.g., quality of greenhouse layout, how it matched your operational needs)?
- In quoting phase would you have needed more information from suppliers? If yes, what?
- In delivery phase would you have needed more information from suppliers? If yes, what
- What is needed to make a complete greenhouse project better and cost efficient?
- If you could now go back in time what you would change or do differently in the last greenhouse project? (5 key findings)

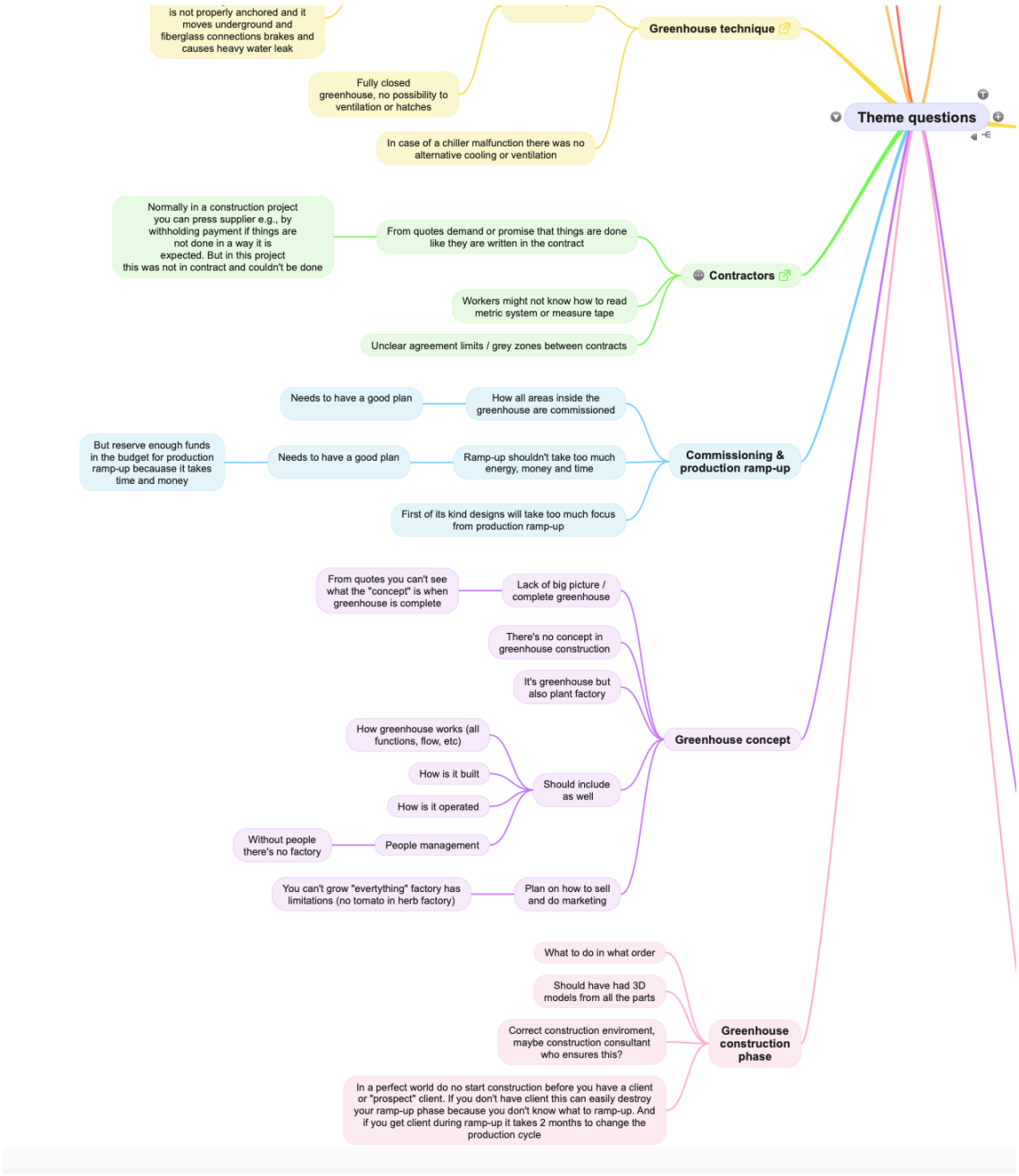
Appendix 2. Delfoy interview open question mind map

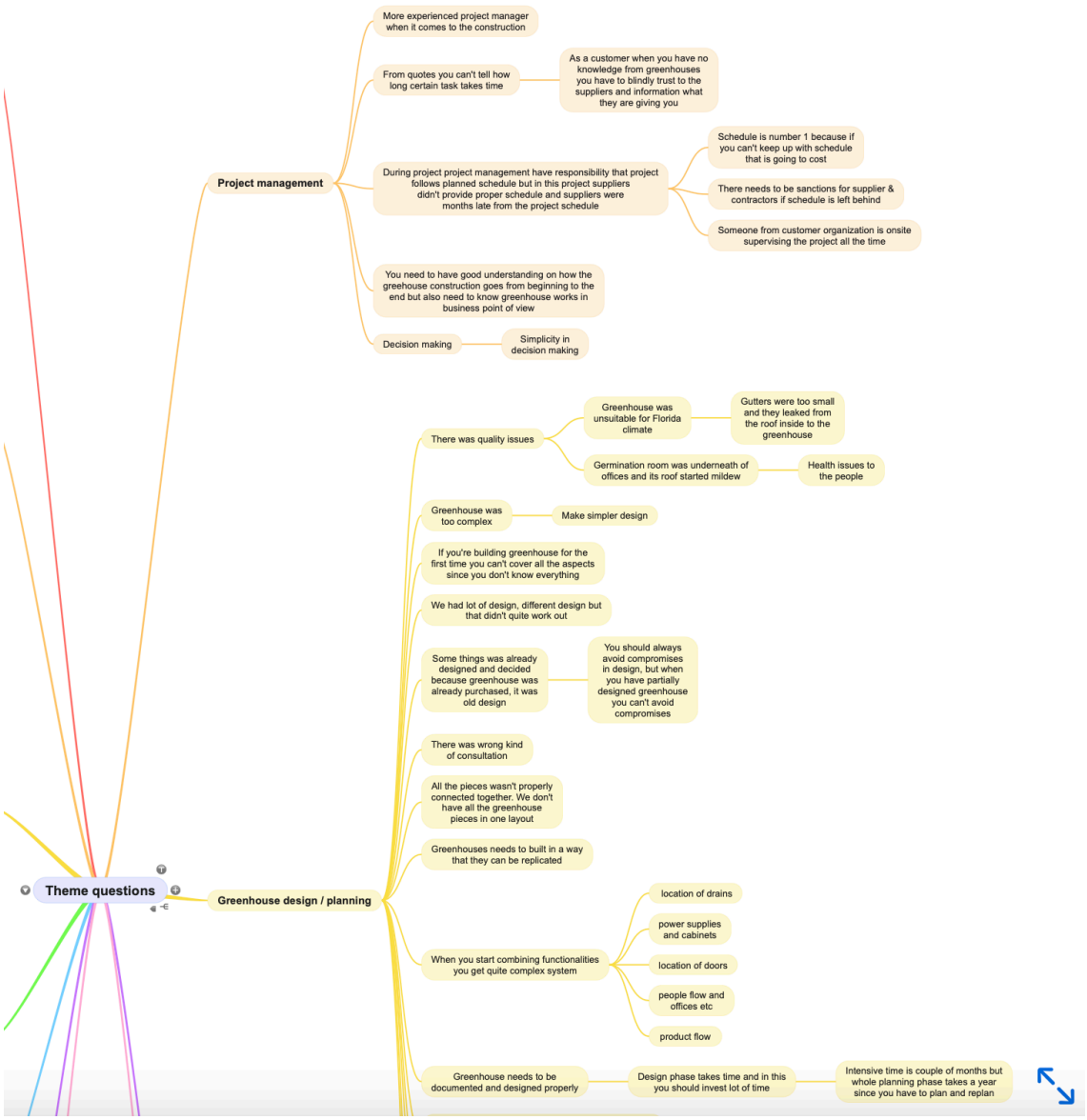


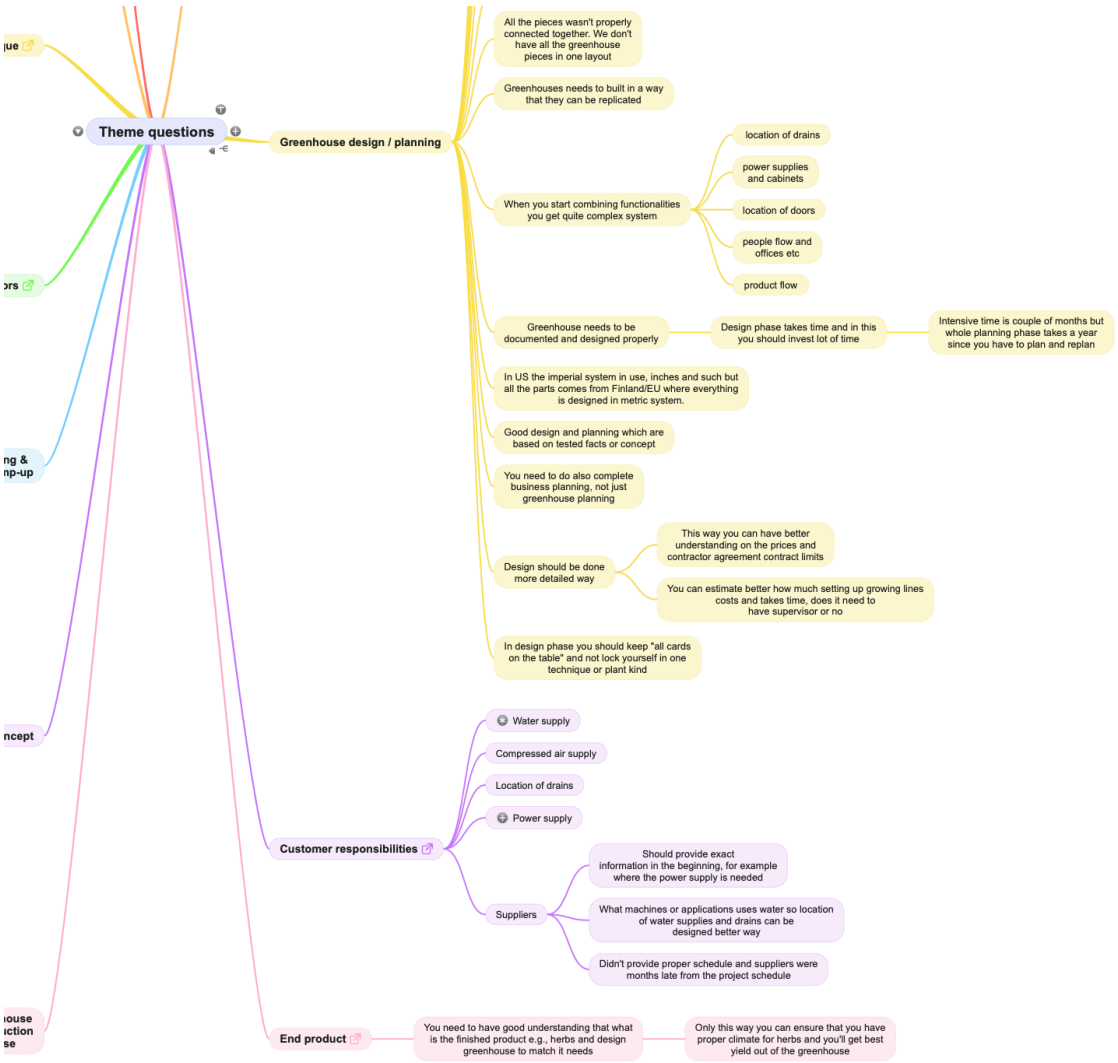

Open question
Greenhouse technique
Cultivation technique
Something else
Hydroponic
Aeroponic
Aquaponic
Why did you chose this technique
Control system of the greenhouse
Who was supplier for growing technology
Decision making
Was there a head grower who made decisions on the greenhouse to match best way on the end product demands
Who did final decision that greenhouse will be built
Was this decision easy to make
Entrepreneur
Investor
Customer
Someone else
Where did the trigger come to start building a greenhouse
Entrepreneur
Investor
Customer
Somewhere else
Customer responsibilities
Water supply
Compressed air supply
Location of drains
Power supply
Greenhouse layout
Was there a clear plan to the layout straight from the beginning
How well layout matched operational needs
Do you want to change something in the layout
End product
Were the end product carefully think before building a greenhouse
Is system flexible if end product is changed

Appendix 3. Delfoy interview theme questions mind map




Theme questions
Greenhouse technique
is not properly anchored and it moves underground and fiberglass connections brakes and causes heavy water leak
Fully closed greenhouse, no possibility to ventilation or hatches
In case of a chiller malfunction there was no alternative cooling or ventilation
Contractors
Normally in a construction project you can press supplier e.g., by withholding payment if things are not done in a way it is expected. But in this project this was not in contract and couldn't be done
From quotes demand or promise that things are done like they are written in the contract
Workers might not know how to read metric system or measure tape
Unclear agreement limits / grey zones between contracts
Commissioning & production ramp-up
Needs to have a good plan
How all areas inside the greenhouse are commissioned
But reserve enough funds in the budget for production ramp-up becausse it takes time and money
Needs to have a good plan
Ramp-up shouldn't take too much energy, money and time
First of its kind designs will take too much focus from production ramp-up
Greenhouse concept
From quotes you can't see what the "concept" is when greenhouse is complete
Lack of big picture / complete greenhouse
There's no concept in greenhouse construction
It's greenhouse but also plant factory
Should include as well
How greenhouse works (all functions, flow, etc)
How is it built
How is it operated
People management
Without people there's no factory
Plan on how to sell and do marketing
You can't grow "evertything" factory has limitations (no tomato in herb factory)
Greenhouse construction phase
What to do in what order
Should have had 3D models from all the parts
Correct construction enviroment, maybe construction consultant who ensures this?
In a perfect world do no start construction before you have a client or "prospect" client. If you don't have client this can easily destroy your ramp-up phase because you don't know what to ramp-up. And if you get client during ramp-up it takes 2 months to change the production cycle


Theme questions
Project management
More experienced project manager when it comes to the construction
From quotes you can't tell how long certain task takes time
As a customer when you have no knowledge from greenhouses you have to blindly trust to the suppliers and information what they are giving you
During project project management have responsibility that project follows planned schedule but in this project suppliers didn't provide proper schedule and suppliers were months late from the project schedule
Schedule is number 1 because if you can't keep up with schedule that is going to cost
There needs to be sanctions for supplier & contractors if schedule is left behind
Someone from customer organization is onsite supervising the project all the time
You need to have good understanding on how the greehouse construction goes from beginning to the end but also need to know greenhouse works in business point of view
Decision making
Simplicity in decision making
Greenhouse design / planning
There was quality issues
Greenhouse was unsuitable for Florida climate
Gutters were too small and they leaked from the roof inside to the greenhouse
Germination room was underneath of offices and its roof started mildew
Health issues to the people
Greenhouse was too complex
Make simpler design
If you're building greenhouse for the first time you can't cover all the aspects since you don't know everything
We had lot of design, different design but that didn't quite work out
Some things was already designed and decided because greenhouse was already purchased, it was old design
You should always avoid compromises in design, but when you have partially designed greenhouse you can't avoid compromises
There was wrong kind of consultation
All the pieces wasn't properly connected together. We don't have all the greenhouse pieces in one layout
Greenhouses needs to built in a way that they can be replicated
When you start combining functionalities you get quite complex system
location of drains
power supplies and cabinets
location of doors
people flow and offices etc
product flow
Greenhouse needs to be documented and designed properly
Design phase takes time and in this you should invest lot of time
Intensive time is couple of months but whole planning phase takes a year since you have to plan and replan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product flow
Greenhouse needs to be documented and designed properly
Design phase takes time and in this you should invest lot of time
Intensive time is couple of months but whole planning phase takes a year since you have to plan and replan
In US the imperial system in use, inches and such but all the parts comes from Finland/EU where everything is designed in metric system.
Good design and planning which are based on tested facts or concept
You need to do also complete business planning, not just greenhouse planning
Design should be done more detailed way
This way you can have better understanding on the prices and contractor agreement contract limits
You can estimate better how much setting up growing lines costs and takes time, does it need to have supervisor or no
In design phase you should keep "all cards on the table" and not lock yourself in one technique or plant kind
Customer responsibilities
Water supply
Compressed air supply
Location of drains
Power supply
Suppliers
Should provide exact information in the beginning, for example where the power supply is needed
What machines or applications uses water so location of water supplies and drains can be designed better way
Didn't provide proper schedule and suppliers were months late from the project schedule
End product
You need to have good understanding that what is the finished product e.g., herbs and design greenhouse to match it needs
Only this way you can ensure that you have proper climate for herbs and you'll get best yield out of the greenhouse

Appendix 4. Questionnaire questions and answers

- Name, company, and position
- Location of the greenhouse
- Accurate location of the greenhouse
- In the greenhouse project your role was?
    - Investor
    - Entrepreneur
    - Project manager
    - Member of project organization
    - (Head) grower
    - Something else
- Where did the trigger come to start building a greenhouse?
    - Entrepreneur
    - Investor
    - Customer
    - Something else
- The year your greenhouse was built.
- Greenhouse cultivation technique?
    - Hydroponic
    - Aquaponic
    - Aeroponic
    - Something else
- Why did you choose this cultivation technique?
- What is your main product?
    - Lettuce (any kind)
    - Herb (any kind)
    - Tomato/pepper/apple (any kind)
- Here you can specify your main product(s)
- Did you have any issues with land zoning and/or permit process
- In your greenhouse you have
    - Cooling system
    - Heating system
    - Growing lights
    - Fully automated cultivation system

    - Semi-automated cultivation system
    - (Energy) curtains
    - Ventilation / hatches
    - Fans or blowers circulating the air
- As a customer were you in charge of these sections in the project
    - General water supply
    - General power supply
    - Air supply to the machines
    - Location of the drains in the greenhouse
    - Greenhouse electrical design
- Was there a head grower who made decisions on the greenhouse to match it best way to the end product demands?
    - Yes
    - No
- How well greenhouse layout matched your operational needs
    - Extremely well
    - Somewhat well
    - Neutral
    - Somewhat not well
    - Extremely not well
- How well you were able to combine cultivation technique with building?
    - Easy, everything found its place without modification
    - Somehow difficult, modifications were needed
    - Many difficulties, big changes were made during machine/technique installation
- During greenhouse commissioning did you get enough help from the suppliers?
    - Yes
    - No
- Here you can share if suppliers could have done something differently in the commissioning
- How would you rate the success of production ramp-up
    - Extremely easy
    - Somewhat easy
    - Neutral

    - Somewhat not easy
    - Major difficulties
- Here you can share thoughts from the production ramp-up
- Which was first?
    - Customer(s) then greenhouse
    - Greenhouse then customer(s)
- Is there a plan to expand existing greenhouse in same location or duplicate in different locations?
    - Duplicate
    - Expand
- Were you able to match your original greenhouse project budget?
    - Stayed under
    - Stayed within budget (+/- 5 %)
    - Went over less than 20 %
    - Went over more than 20 % but less than 50 %
    - Went over more than 50 %
- Is there something unique in your business what differentiates you from the other greenhouse companies?
    - Production or product
    - Cultivation technique
    - Patents
    - Design protection
    - Location (no competition)
    - Something else
- Here you could share your thoughts if you chose "something else" on question 24
- Was there an external company who oversaw the greenhouse construction phase?
    - Yes
    - No
- Did you have a clear picture straight from the beginning what the finished greenhouse is going to look like?
    - Yes
    - No

- Did you have any problems in the material logistics or deliveries during the project?
    - Yes
    - No
- If you had problems with material logistics and deliveries what kind of problems, there were?
    - Most of the materials came from outside US in containers
    - Materials came in containers, and it was time consuming to unload them
    - Too many deliveries at the same time
    - Deliveries were late
    - Materials were laying on the ground at the site in a wrong way
    - Shortage on the materials and urgent airfreight was needed to use
    - Materials got lost during transportation
    - No proper check-up lists to confirm what is shipped and received
    - Inadequate markings in the materials
- Here you can share your thought on materials logistics and deliveries
- In the complete greenhouse project what was the most challenging part
    - Land zoning and permits
    - Material logistics and deliveries
    - Greenhouse commissioning and production ramp-up
    - Greenhouse construction phase
    - Taking care of water and power supply for the building and machines
    - Project management
    - Greenhouse design / planning phase
- If you could change something in the finished greenhouse what it would be?
    - Greenhouse size
    - Greenhouse location
    - Greenhouse layout
    - Cultivation technique
    - End product
    - Growing tables
    - Seeding machine(s)

    - Something else
- You could share your thoughts in here if you answered "something else" on previous question
- Would you have needed an external partner or company to help you go through a greenhouse project from start to finish?
    - Yes
    - No
    - Maybe
- Open comments or additional info on the questions