Innovation Model for Agrivoltaics Business Development in Finland

Maria Seppälä

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Innovation model for Agrivoltaics Business Development in Finland

Maria Seppälä
Leading Sustainable Growth
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Maria Seppälä

Innovaatiomalli maatalousaurinkosähköhankkeiden kehittämiseen Suomessa

Vuosi 2024 Sivumäärä 61

Tämän opinnäytetyön tavoitteena oli luoda alustava innovaatiomalli maatalousaurinkosähkö-hankkeiden kehittämiseen Suomessa. Opinnäytetyön aihe kumpusi omasta kiinnostuksesta kestäviin liiketoimintamalleihin, energiamurrokseen ja maankäyttöön. Myös keskeisenä mielenkiinnon kohteena oli tarkastella potentiaalisia uusia ansaintamalleja maanomistajille sekä erityisesti maanviljelijöille, jotta he voivat ylläpitää kestävästi ja kannattavasti myös nykyistä maanviljelyliiketoimintaansa ja ruokaturvaa Suomessa. Tämä opinnäytetyö on toteutettu itsenäisesti, eikä tätä ole tehty kolmannen osapuolen toimeksiantona.

Tietoperustassa käsitellään maatalousaurinkosähköä yleisesti, sen historiaa sekä hyviä ja huonoja puolia sekä maanviljelijöiden mielipiteitä näihin liittyen ja mahdollisia tulevaisuuden näkymiä. Opinnäytetyössä käsitellään myös energiamurrosta ja Suomen hiilineutraaliustavoitteita sekä maankäyttöä tähän liittyen. Myös maatalouden nykytilaa Suomessa käsitellään ja käydään läpi Euroopan Unionin yhteistä maatalouspolitiikkaa (YMP, englanniksi Common Agricultural Policy = CAP). Opinnäytetyössä käydään myös läpi kestävää kehitystä sekä kestävien liiketoimintamallien kehittämistä.

Opinnäytetyön tavoitteen saavuttamiseksi luotiin kyselytutkimus, jonka avulla oli tavoite kerätä tietoa maanomistajien ja viljelijöiden mielipiteistä ja näkemyksistä maataloussähkö-hankkeisiin liittyen. Kyselyn avulla oli tarkoitus myös selvittää maanomistajien ja viljelijöiden sekä heidän maanviljelytoimintaansa liittyviä tekijöitä, joiden pohjalta oli tarkoitus mm. selvittää, mitä tekijöitä maanviljelijät arvostaisivat tärkeiksi liittyen maataloussähköhankkeisiin, mikäli he itse lähtisivät mukaan tällaiseen liiketoimintaan.

Tietoperustassa käsiteltyjen teemojen sekä kyselyn vastauksien pohjalta luotiin innovaatiomalli pohjautuen kestävän arvonluontimallin viitekehykseen maataloussähköhankkeille. Tuloksena myös tunnistettiin neljä keskeistä elementtiä, joiden pohjalta liiketoimintaa tulisi lähteä kehittämään yhdessä eri sidosryhmien kanssa. Maataloussähköhankkeet myös tarjoavat paljon jatkotutkimusaiheita niin teknistaloudellisista näkökulmista kuin maanviljelyn näkökulmasta.

Asiasanat: maatalousaurinkosähkö, maanomistajat, energiamurros, kestävien liiketoimintamallien kehittäminen

Laurea University of Applied Sciences **Abstract**
Leading Sustainable Growth
Master of Business Administration

Maria Seppälä

Innovation Model for Agrivoltaics Business Development in Finland

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The purpose of this thesis is to create a preliminary innovation model for agrivoltaics business development in Finland. The subject of the thesis was born out of a personal interest in relation to sustainable business models, energy transition and land use. One main interest was also diversifying options on how farmland owners and especially farmers can increase their profit from their operations sustainably in order to also maintain their current business operation and food security in Finland. This thesis was not commissioned by any company or organization.

In the literature review, the thesis covers the term agrivoltaics, its history, benefits and disadvantages as well as farmers' opinions and possible future developments. It also looks into the energy transition in Finland and land acquisition aspects related to it, and then proceed to cover the current state of agriculture in Finland. Agriculture in Finland is highly influenced by directives from the European Union, and therefore the Common Agricultural Policy is also reviewed. Theory related to sustainable business models is also looked into in order to provide insight into how for example sustainable business model development differs from traditional business model development.

In order to gather information regarding agrivoltaics and farmers opinions towards it, a questionnaire was created that gathered information on farmers and landowners and their farms' characteristics. The purpose of the questionnaire was to gain understanding on different possible factors that landowners would consider important in regard to agrivoltaics systems and if they would be interested in including such systems as part of their land and farming operations.

Based on the literature review and results of the questionnaire, an innovation model was created to provide a preliminary framework for agrivoltaics business development in Finland. The questionnaire consisted of both qualitative and quantitative questions. The main finding of the thesis is that there are four key topics which should be addressed and examined thoroughly in the agrivoltaics business development phase through a sustainable value proposition framework. Agrivoltaics is also a subject that provides a vast amount of topics for further study – from technical and financial aspects to farming practices and crop varieties.

Key words: agrivoltaics, landowners, energy transition, sustainable business development

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1 Introduction

The purpose of this thesis is to develop a preliminary innovation model for agrivoltaics business development in the early stages of the business and specifically targeted towards the co-creation of the business model with one of the key stakeholders – landowners and farmers. Agrivoltaics refers to the dual use of land in which agricultural crops and solar panels are both placed in the same area in order to make more efficient use of the land for both food and energy production. In the beginning of the thesis, the term and principle of agrivoltaics systems is reviewed as well as the possible benefits as well as disadvantages of the systems. Farmers' opinions and adaptation to such systems as well as new innovations in general are also looked into as well as the future development of agrivoltaics systems. Then I proceed to briefly review the current energy transition and carbon neutrality goals in Finland from the perspective of solar energy and land acquisition. The following chapter after this focuses on the current state and future predictions of agriculture in Finland. Then I examine the meaning of sustainability in general as well as sustainable business models and innovation.

Based on the theoretical information presented in the chapters, a questionnaire was built and presented to farmers and farmland owners. The goal of the questionnaire was to gather information and to provide insight to the thoughts of farmland owners related to agrivoltaics in order to gain knowledge if agrivoltaics is something farmers and landowners would be interested in integrating into their operations, and if so with what terms, and if not, then to clarify the reasons why the option of agrivoltaics currently would not be a viable option to them. Based on the gathered information and literary review, a theoretical guideline and key elements to focus on when developing an agrivoltaics business was created, so that the main issues and concerns of farmers and landowners can be focused on when developing the business model together with different stakeholder groups.

2 Literary review

The following literary review consists of different themes that are related to agrivoltaics and agriculture, energy transition and sustainable business development. These different themes are interlinked when considering the goal of this thesis which is to create a preliminary innovation model related to agrivoltaics business development in Finland. The purpose of the model would be to some extent provide a guideline on how to proceed with such business development, when considering the challenges and benefits of agrivoltaics to farmers and other related stakeholders in the current market environment, which is affected by energy transition and carbon neutrality goals as well as the current situation of farmers and the challenges the agricultural sector is currently facing.

2.1 Agrivoltaics

In this chapter I explain the term agrivoltaics and the background and history related to it. I then review the benefits and disadvantages of agrivoltaics that have been studied thus far and also look into the growing market related to solar power and agriculture dual use in different countries as well.

2.1.1 History and recent developments of agrivoltaics

Agrivoltaics (also known as Agri-PV and maatalousaurinkosähkö in Finnish (Suontlahti 2024, 3)) is a term that describes the combination of agriculture and energy production via solar panels on the same area of land. The term originates from the 1980's when Armin Zastrow and Adolf Goetzberger researched the possibilities for dual use of farming crops and implementing solar panels in the same land area. Adolf Goezberger is the founder of Fraunhofer Institute of Solar Energy Systems – a German establishment focusing on applied solar energy research founded in 1981. More experiments and research on the matter have been performed in recent years and for example research done by Dupraz et. al (2011) is widely cited as it suggested that agrivoltaic systems could have 35 - 73% increase in global land productivity. (Dos Santos 2020, 10-11; Dupraz, Marrou, Talbot, Dufour, Nogier, & Ferard 2011, 2725; Fraunhofer ISE, 2023) Term agrivoltaics is commonly used, but also terms agrophotovoltaics, agrovoltiacs and photovoltaic agriculture can be used (Chalgynbayeva, Gabnai, Lengyel, Pestisha & Bai 2023, 9).

Switching to renewable energy resources is required in order to tackle climate change and solar power is seen as a viable option to reduce emissions in different countries in order to do so especially due to the decreased cost of the panels in recent years (Reasoner & Ghosh 2022, 1; Dias, Gouveia, Lourenço & Seixas 2019, 725). The implementation of large-scale photovoltaic systems however can bring up conflicts related to land use, since the ideal conditions for photovoltaic panels are areas with great amount of exposure to solar radiation, light winds, low humidity as well as moderate temperatures. The same conditions are also ideal for agricultural crops, which means that the large-scale photovoltaic systems can be seen as a competitor for agriculture land use (Dinesh & Pearce 2016, 1-2; Adeh, Good, Calaf & Higgins 2019, 3).The COVID-19 pandemic and the war in Ukraine has had their effect on the global supply chains, food security as well as energy prices and financial markets in general, and considering the effects climate change also has in different areas around the world directly and indirectly for both agriculture and energy consumption and infrastructure, agrivoltaics can be seen a one solution to provide both food security and energy security and this way increase the resilience of energy and food systems. (Chalgynbayeva, Gabnai, Lengyel, Pestisha & Bai 2023, 1 & 4)

2.1.2 Benefits and disadvantages of agrivoltaics

One of the main benefits of agrivoltaics is considered the opportunity of dual use of land as it is a way of combining the production of clean and renewable energy as well as food production. This way it promotes resource efficiency, provides a solution to the conflict between choosing one over the other (energy vs. food production) when it comes to land use and also creates a new source of income to farmers and make their business more profitable. Based on a study by Fraunhofer ISE (2017) the dual use of land can increase the land use efficiency by 60% (Figure 1).

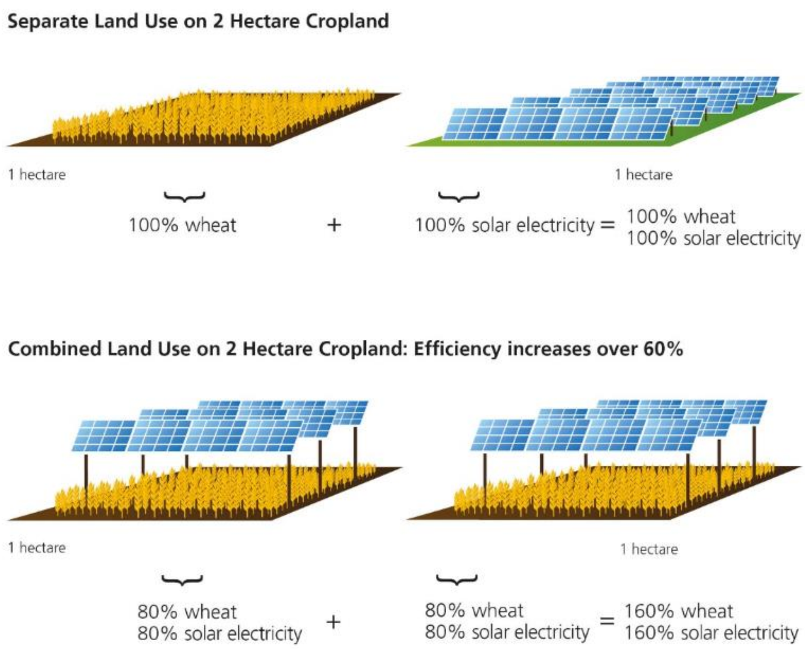

Figure 1: Land use comparison between wheat and solar electricity (Fraunhofer ISE 2017)

However, the investment cost for agrivoltaic systems is higher than regular photovoltaic systems. With agrivoltaics system, the factors increasing the cost are primarily due to mounting structures, site preparation as well as soil protection which require more careful consideration than regular photovoltaic systems. (Chalgynbayeva, Gabnai, Lengyel, Pestisha & Bai 2023, 6)

Agrivoltaic systems can also benefit the crops itself by aiding their growth by creating a micro-climate underneath the panels due to the shade they provide, which can increase soil moisture and lower the temperature, and this way reduce the need for additional irrigation which helps reserve water itself but also provide additional savings. Considering this, agrivoltaic systems could provide possibilities for better crop yield in climate areas that suffer from excessive heat and lack of water. Micro-climates can also help increase the panel efficiency, due to its cooling effect, since higher temperatures correlates with decreased photovoltaic panel efficiency. However, a lot is depended on the optimization of the panel layout, so it is important to find the most suitable layout and orientation of panel angles that provide both the benefits to the crop and soil but also consider the optimal factors from energy production perspective. (Reasoner & Ghosh 2022, 6-10)

While dual land use can be seen as a benefit, there are still many problematic factors to address when combining agrivoltaic systems and farmland. Photovoltaic systems usually take up a very large amount of land area, which can create social acceptance issues with local communities. The photovoltaic systems can also be seen as counteracting sustainability goals such as biodiversity preservation while they would in turn provide renewable energy. (Scognamiglio 2016, 630)

Based on research done by Chalgynbayeva et. al (2023, 20), the main crops that have been studied regarding agrivoltaic systems have been wheat, barley, tomato, lettuce, and soybean. They suggest in their research, that for agrivoltaics system development to move forward, more comprehensive studies should be conducted with other crops as well and include other factors into the research such as technical and social adaptation, long term economic consequences as well.

Since the overall effects of large scale photovoltaic systems to environment is not yet fully known and researched, Sanna Andersson from the Ministry of Environment highlights in an interview in Maaseudun Tulevaisuus, that ideally large scale photovoltaic systems would be built on brown fields and in areas that already have built environment present, since there is no solid information yet on how the panel installations will affect soil conditions and if returning the land to agricultural use after the photovoltaic system has reach the end of its lifecycle is actually possible. (Koskiahde 2023 A) While investing in renewable energy can be seen as a positive thing, environmental aspects need to be considered more holistically and for example if forests are cut down due to the construction, this will have negative affects when considering carbon capture. Also, if agricultural land is used for large scale photovoltaic systems this can be seen problematic for example from the perspective of security of food supply even though the energy investment then on the other hand could increase the security of energy supply. (Koskiahde 2023 B) Currently the Finnish Food Authority has defined, that land which is allocated to solar panels is not applicable for farming subsidies, but if the area between panels is otherwise applicable for agricultural use and if the area is wide enough to enable farming, this area can be considered applicable for farming subsidies, if the farmer applying the subsidies is in control of the land area in question and if the panels do not cause harm to the crops via shading. (Ruokavirasto 2024)

2.1.3 Farmers opinions and attitudes towards agrivoltaics

Chalgynbayeva et. al (2023, 20) also highlight in their study, that it would be important to study why farmers would accept agrivoltaic systems as part of their operation and approve those to be installed to their land, stating that valid business cases related to agrivoltaic systems are required in order to make them more known and attractable to landowners and farmers. Based on a study conducted by Pascaris, Schelly and Pearce (2020) the main concern that emerged regarding agrivoltaic systems was land viability – meaning that while he possibility of additional revenue and more stable income through energy production was recognized and appreciated, farmers needed more reassurance that the land would remain viable and in good quality for agricultural use in the future as well. As business owners, farmers also highlighted the need for flexibility and adaptation to changing market conditions regarding the implementation of agrivoltaic systems. The contracts to rent the land for photovoltaic systems are usually long, and in the research one person had mentioned that if the contract is signed for 25 years, during that time the agricultural market can change drastically and this could then in turn change the need for the use of the land in the agricultural operations somehow, and the long contracts might hinder the business operation adaptability to the change and the resilience of it through that. Trust between the farmers and companies involved in the agrivoltaic system build up, operation and maintenance was also seen as a key element. (Pascaris, Schelly Pearce 2020, 5-6, 9)

Regarding traditional photovoltaic systems, Maaseudun Tulevaisuus created a questionnaire that was targeted to landowners near Oripää to ask about ongoing investments related to photovoltaic systems and what to ask landowners opinions on them. Based on the results, in the area where the questionnaire was sent, there were approximately 3 000 hectares that were in process to be reserved for photovoltaic systems, and partially this would cover crop lands and forests as well. Mainly the attitudes were described as positive, but negative concerns were also brought up, and for example the changes in the traditional countryside landscape are something that people find troublesome. Municipalities are also interested in the projects since it brings real estate tax income to the municipalities. For the landowner itself, the rent prices vary from a few hundred euros to 2000-3000 euros per hectare. (Niittymaa 2023)

2.1.4 Sustainable intensification - early adopters and farmers motivations

The agricultural sector is facing challenges globally to feed the growing population while adapting to climate change. As also discussed in chapter 2.1.2., with the rise of renewable energy demands, the need for land is also increasing in this area and solar energy especially is highly land intensive. Sustainable intensification refers to land use practices that increase cropland productivity while minimizing environmental externalities. Khanna and Miao (2022) present in their research elements that can support farmers adoption to, for example agrivoltaics. These understandably include behavioral factors such as farmers personality, attitudes toward changes, personal values, farming objectives as well as social factors such as social norms and involvement in social comparison. They also find that since there are many factors that influence the farm's characteristics – such as soil quality, location, size, water availability, environmental sensitivity – technology adoption of farmers is influenced by the farm's characteristics. Enabling environment also plays part in adopting innovation and technologies as well as financial incentives, but the since the adoption willingness is affected by different variables related to the characteristics of the farm and farmer itself, there is not one singular formula to determine the willingness to adopt. (Khanna & Miao 2022, 2, 9-10)

David F Midgley and Grahame Dowling also provide a simplified model that can be used to detect and analyze what factors enhance early adoption and later adoption (Figure 2). The innate innovativeness or lack of it provides the starting point, which then provide a route where the willingness to adopt new innovations depends on the interest or lack of it related to the product category, favorability of the situation or communicated experience, which then can lead to either early adoption or later adoption or no adoption at all if there are no interest in the product category, no favorable communicated experience received during the process or no favorable situation present. If there is interest in the product category, favorable experiences received and favorable situation present, early adaptation is more likely to happen. (Midgley & Dowling 1978, 237)

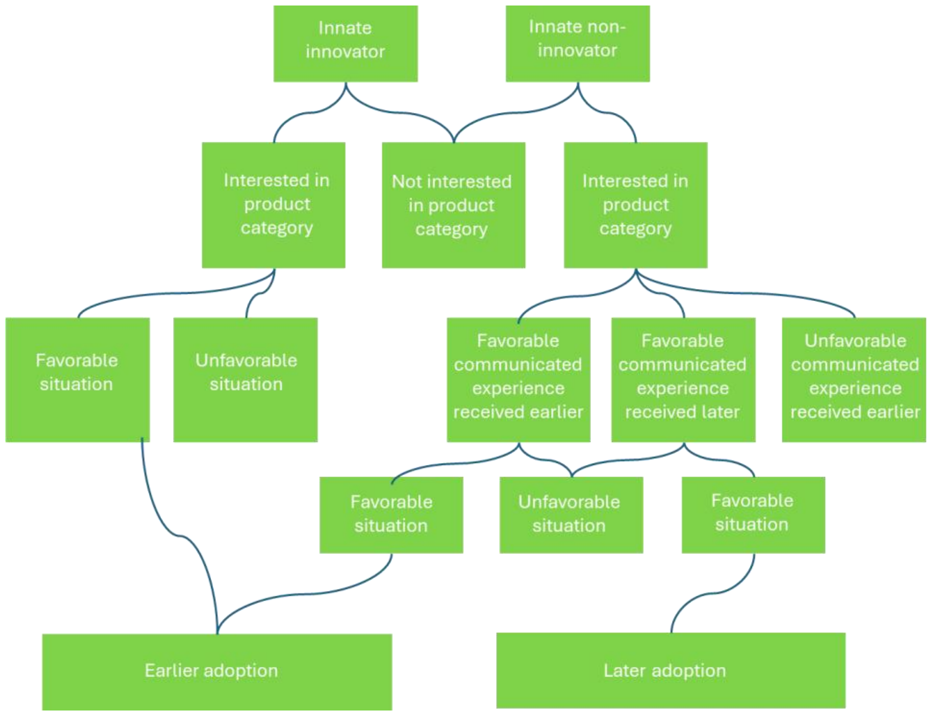

Figure 2: Based on Midgley and Dowlings simplified tree version of the adoption willingness (Midgley & Dowling 1978, 237)

2.1.5 Agrivoltaics future developments

Agrivoltaic systems are seen as one solution to move towards clean energy transition while maintaining food security. The agrivoltaics market is expected to be worth 9,3 billion USD by 2031. However, subsidies from the government will most likely be required in order to promote the growth as well as legislation modifications in order to accelerate the implementations. (Shoeck 2023)

Countries such as Croatia and Italy have made efforts to alleviate the bureaucracy related to agrivoltaic systems to facilitate the future deployment more efficiently and to separate the application procedures from regular photovoltaic projects (Matalucci 2023; Maisch 2023). In France agrivoltaics is also seen as one of the key elements for the country to detach itself from fossil fuels in the upcoming years (PV Magazine 2023). In United States, senators Martin Heinrich from the democratic party and Mike Braun from the republican party proposed the Agrivoltaics Research and Demonstration Act which would provide funding 15 million USD per year during 2024 to 2028 targeted for agrivoltaics research and demonstration projects (Heinrich 2023).

Based on research made in Aarhus University, agrivoltaic systems could have the potential capacity of 51 TW in Europe, while producing up to 71 500 TWh of electricity per year. This is 28 times higher than current electricity demand in Europe. However, the suitability of land area varies greatly between countries, for example only 1% of Norway's land area can be considered suitable for agrivoltaics, while in Denmark the amount of area can be up to 58 %. (Khan Niazi & Victoria 2022, 10)

2.2 Energy transition in Finland

In the following chapter I examine the currently on-going energy transition in Finland by reviewing the carbon neutrality goals to which Finland has committed to and examine what these mean from the renewable energy perspective. I then investigate specifically the status of solar energy in Finland and also land use and land acquisition aspects related to renewable energy production.

2.2.1 Carbon neutrality goals and transition to renewable energy

Finland aims to be carbon neutral by the year 2035. The policies set in the European Union provide guidelines and demands also for Finnish climate policies, and the EU has set out a target to be the first carbon neutral continent in the world by the end of 2050. In the national Medium-Term Climate Change Policy Plan national emissions are analyzed through effort sharing sectors, that include building-specific heating, off-road mobile machinery, agriculture, transport, waste management ja F-gases. The current state of each of these factors are presented in the plan as well as strategies and actions to minimize emissions in the future. (Ympäristöministeriö A)

The emission reductions related to agriculture are said to mainly be following the procedures of European Union's commons agriculture policy which is discussed more in chapter 4.2. In the policy plan the focus areas related to decreasing emissions caused by agriculture is focused mainly on limiting clearing of new farming fields, limiting peat lands use in farming, afforestation, increasing farming practices that promote carbon capture as well as promote organic farming. The plan also highlights factors such as changing diets preferences and avoiding food waste as actions that every person can act upon to support the emission reductions related to agriculture. (Ympäristöministeriö 2022, 103, 107–116)

From an energy perspective the plan highlights the Renewable Energy Directive, the Energy Efficiency Directive, and the Directive on Energy Performance of Buildings, which are common directives for the European Union. The purpose of the Renewable Energy Directive is to promote the use of renewable energy in the overall electricity production, heating, cooling and in traffic. The directive does not determine national goals, but each member country is to set the targets for themselves in such a way, that all member countries combined the amount of renewable energy use within EU is at least 32 % from the overall end use of energy by the year 2030. (Ympäristöministeriö 2022, 32) Finland has set its target to be at least 51 % of renewables from the overall end use by the year 2030. (Motiva 2024)

Finland's transmission operator Fingrid has said that sector integration will help reach this goal, and they published Energy System Vision 2023 which consists of four different visions for energy systems and electrification in Finland for the upcoming decades. The four visions consist of 1. Power to Products, 2. Hydrogen from Wind, 3. Windy Seas and 4. Local Power. The different visions are based on different potential scenarios and then examine how the scenarios will affect, for example the transmission infrastructure and its development. In the Power to Products scenario Finland will become a significant importer of P2X products that refer to for example carbon neutral synthetic fuels such as green hydrogen, e-methanol, and e-kerosene, which will mean in turn that wind and solar power production will increase significantly. (Fingrid 2023, 7; Fingrid 2020; Fingrid 2020 B; Ørsted 2023)

Hydrogen from wind is similarly a scenario, where Finland will produce green hydrogen which is enabled through renewable energy systems. In the Windy Seas scenario, the electricity production via wind farms is focused in offshore wind farms and the transmission of electricity from the west coast to consumption concentrations will provide challenges to the transmission infrastructure. In the Local Power scenario, the consumption of energy is not as massive at it is thought to be in the other three scenarios, and the focus of the production will be on the southern parts of Finland near the main consumption areas and means of electricity production is a balanced mix of wind and solar power as well as nuclear power provided by small modular reactors (SMR). (Fingrid 2023, 7)

Sector integration (also known as sector coupling) is seen as one of the means to achieve a more sustainable energy system in the future. It basically means, that for example different industry sectors overlap and help adjust the energy systems as well as act as an energy provider. This means that for example electric cars can be used as energy storages and large factories that produce excess heat as a byproduct in their production can provide that heat to the district heating system. In the future, the sector coupling will intensify and different kinds of digital solutions as well as artificial intelligence solutions will enable the development of sector integration. (VTT, 4, 10; Energinet) In relation to agriculture, sector integration is seen as the use of residual products that come from agricultural operations. (Energinet)

2.2.2 Solar energy in Finland

Solar energy is one of the renewable energy sources, and the use of it has grown steadily in Finland for the past years and in 2021 the capacity of solar electricity grew approximately 100 megawatts. Most of the solar electricity systems connected to the grid currently are less than 1 MW. From the plant register maintained by the Energy Authority in Finland there were all together 12 over 1 megawatt (maximum capacity) solar plants in Finland in April 2024 with the combined capacity of 50,2 MW. The amount of large-scale solar plants has grown rapidly, since in June 2022 the combined capacity was 4,6 MW, and a year later in June 2023 it was 34 MW. According to the Energy Authority, the off grid solar electricity capacity in June 2023 was approximately 22 megawatts. The off-grid capacity consists mainly of panels attached to summer cottages and other private residents. (Energiavirasto 2022, Energiavirasto 2023)

Despite the longer darker period due to winter, solar energy is a very viable option as a renewable energy source in Finland. The irradiation in Southern Finland is for example comparable to the levels of Northern Germany and the use of solar power in Finland is supported by the summer season, during which the sunlight is available almost round the clock. The efficiency of the solar panels is also better in cooler climates, which promotes the use of the panels in Finnish climate. In higher latitude areas, the direction of solar rays is lower, which also provides the option to attach panels on vertical surfaces, for example on the walls of supermarkets and industrial buildings. Vertical mounting then minimizes the negative effects of snow covering the panels, which is usually the case with panels mounted on rooftops. (Motiva 2022; Vattenfall 2022; Formolli, Lobaccaro & Kanters 2021, 2)

2.2.3 Land acquisition for renewable energy production

Transition from fossil fuels to renewable energy production will increase the need for land use related to energy production. Renewable energy will require roughly four to six times the land area when compared to coal per unit of electricity produced. (Kennedy & Qayyum 2023, 3) Ideally the land used for large scale renewable energy production would be areas that are called brownfields, which refer to land areas that might have been contaminated with hazardous chemicals such as pesticides or heavy metals, and which are not possible to be used for land development unless the area has been thoroughly cleaned and cleared from the contamination. Brownfields are areas which are usually located in old industrial areas for example and can provide challenges for cities since real estate development for such areas is not an attractive option in most cases. Greenfield development in turn refers to development done to previously undeveloped land, such as rural agricultural land. Therefore, it can be considered that the more socially acceptable way to increase solar power capacity is to build the required infrastructure on areas that are considered brownfields, since they already tend to have certain level of infrastructure in place and the land has already been developed to a certain extent. This way increasing the amount of renewable energy would not take away from food production, housing, tourism, and other more socially accepted priorities for land use. (Adelaja, Shaw, Beyea & Charles McKeown 2010, 7021-7023)

In Finland, companies such as Solarigo, Neova Group, Ilmatar and OX2 provide information on their website to landowners regarding the land acquisition process related to renewable energy and encourage landowners to contact them. Neova Group mentions that for solar power generation, they mainly look for large peat extraction sites that are no longer in use while OX2 mentions that they also look for low yield farmland. (Neova Group, OX2, Solarigo, Ilmatar) For municipalities, the real estate tax income makes solar power projects attractive, since they can be even higher than the rent per hectare. (Pesu 2023) Using farmland solely for solar power plants has created concerns for farmers in Spain, since they are concerned that the energy companies renting the land take advantage of the landowners by not creating beneficial contracts with the farmers, and the Spanish government has made it easier for energy companies to get access to farmland. The farmers also share their concern regarding the price of farmland going up since the solar plants are taking up space from agriculture, and how it will affect the future of agriculture and food production in Spain. (Salmi 2023)

The Central Union of Agricultural Producers and Forest Owners (Maa- ja metsätaloustuottajain Keskusliitto in Finnish, abbreviation MTK) provides assistance and guidelines for landowners related to wind farm and solar energy land acquisitions for example giving out contract templates for landowners to use as well as legal assistance. The Union has also created a guidebook related to wind farms for landowners in order to provide information but also to ensure that landowners are aware of their rights when it comes to dealing with energy companies that are interested in land acquisitions. (MTK; MTK 2022)

2.3 Agriculture in Finland

The following chapter 2.3.1 briefly covers the current state of agriculture in Finland by reviewing the current structural conditions as well the profitability aspects of farms. In chapter 2.3.2 the European Union’s Common Agricultural Policy is examined and in chapter 2.3.3 the future predictions of agriculture in Finland are analyzed from the perspective of what the structural changes related to for example the average age of farmers and majority agricultural landowners will mean in the upcoming years.

2.3.1 Current state of agriculture in Finland

In 2022 there were 43 611 practicing farmers and commercial gardens in Finland. Throughout the decade the number of farms has declined almost 22 % while at the same time the average size of farms has increased by 11 hectares. In 2012 the average sized farm was 41 hectares while in 2022 it was 52 hectares. The growth can be explained by the structural change that is happening in the agricultural sector – older farmers are shutting down their business when there is no suitable person to carry on the practice and this frees up land for active farmers to rent out or to buy. The average age of active farmers in 2022 was 54, and less than 14 % of farmers in 2022 were below 40 years old. One third of the agricultural land currently in use in Finland is owned by farmers in the age group 55 - 64. (Latvala, Väre & Niemi 2023, 54-55)

Global events and geopolitical issues also have their effects on the Finnish agricultural sector. Russia's war on Ukraine has caused limitations to the supply of fertilizers and thus raised their price. The price of other production inputs - such as gas and electricity – have also risen in the past few years, which have had negative effects on the profitability of farms, which also depend highly on varying weather conditions as well and globally especially drought is a problem in the Middle East, Argentina, and certain parts of the USA (Luke 2022). The average profitability coefficientof farms in 2022 was 0,46 and the average salary of a farmer was 7,5 euros per hour while the return on equity was 1,5 %. Profitable farms usually co-operate more between other farmers than non-profitable farms, and farmers who run a more profitable business are usually more open to using new technologies and developing their skills in various areas such as marketing and sales in addition to farming. While there isn't a fit for all solution to a profitable farming business, being up to date on current developments through various news outlets, professionals and educational opportunities can assist in increasing profitability of the farming operations as well as taking care of the physical and mental health of the farmer itself to maintain and upkeep the ability to work. (Latvala, Väre & Niemi 2023, 57; 64-65).

2.3.2 Common Agricultural Policy

Common agricultural policy (abbreviation CAP) is a partnership between farmers and society in the European Union. The main goals are to safeguard European farmers and enhance the productivity of agriculture and sustainable management of natural resources within EU countries. It also sets out to tackle climate change and maintain landscapes and rural areas across the EU. One other main goal is also to ensure a stable supply of affordable food for EU citizens. (European Comission A) The current CAP period is built around 10 key objectives for the period 2023-2027, which each EU country has used as a guideline for their country specific CAP strategy, which are listed below and shown in Figure 3. (European Comission B)

1. To ensure a fair income for farmers
2. To increase competitiveness
3. To improve the position of farmers in the food chain
4. Climate change action
5. Environmental care
6. To preserve landscapes and biodiversity
7. To support generational renewal
8. Vibrant rural areas
9. To protect food and health quality
10. Fostering knowledge and innovation

Figure 3: The 10 objectives of common agricultural policy (European Comission B)

For example, with climate change action, the target is to contribute to the mitigation of climate change by, for example, promoting renewable energy. Vibrant rural areas, fair income and generational renewal means that actions are taken to make sure farmers can make a living with their operations, that the operations itself is attractive enough for the next generations to continue and thus enable vibrant rural areas. (European Comission B) The focus in Finland related to the CAP objectives is active food production, environmentally friendly agriculture and countryside that promotes vibrant rural areas as well as generational renewal. In addition to this, one of the key elements is also to promote knowledge and innovation as well as digitalization. The goal of the strategy is to ensure a fair income for farmers. (Maa- ja metsätalousministeriö)

2.3.3 Future predictions regarding agriculture

By the year 2030 it is predicted that the number of farms in Finland will decrease to around 35 000. One of the main trends in the future is predicted to be the increase in farm size while the amount will decrease. Currently one fifth of the largest farms in Finland produce almost 60 % of the agricultural products in Finland. On the other hand, profitability can be achieved through specialization – meaning that the farm can further produce the products at the farm as specialized end products. In the year 2030 data will also play a major role in agriculture. Currently data is already collected from various data points related to for example feeding plans of cattle, milking machinery and crop land productivity and quality. As digitalization moves forward, more integrated systems will be in place that will help optimize farming practices and enable more profitable operations. (Latvala, Väre & Niemi 2023, 65–67; Pesonen, Haapala, Hyväluoma, Kallio, Karjalainen, Linn & Ruponen 2022, 4)

Climate change, carbon neutrality goals, sustainability topics such as loss of biodiversity as well as sustainable food systems in general create both challenges and opportunities for the agricultural sector in the future. Due to global warming, the viable timeframe for growing crops might increase, but this can also promote the spreading of different diseases that affect crops and animals. The benefits of longer periods of warmer weather however depend on how the rainfall is spread throughout the growing season. Farmer also need to prepare for changing conditions through careful crop selection in favor of more resilient varieties and with suitable farming practices. (Lehtonen & Rämo 2022, 425; Ilmasto-opas) For example carbon capture through farming practices promotes circular economy and increases the sustainability of the farming operations, and different payment scenarios and mechanisms related to carbon capture has been examined by the Policy Department for Structural and Cohesion Policies in the European Union which are presented in the Figure 4, where MRV means measurement, reporting and verification. Therefore, while climate change will inevitably have its negative effects on agriculture, through mitigation efforts this can also mean new revenue opportunities for farmers. (Andrés, Doblas-Miranda, Rovira, Bonmatí, Ribas, Mattana, & Romanyà 2022, 76-78)

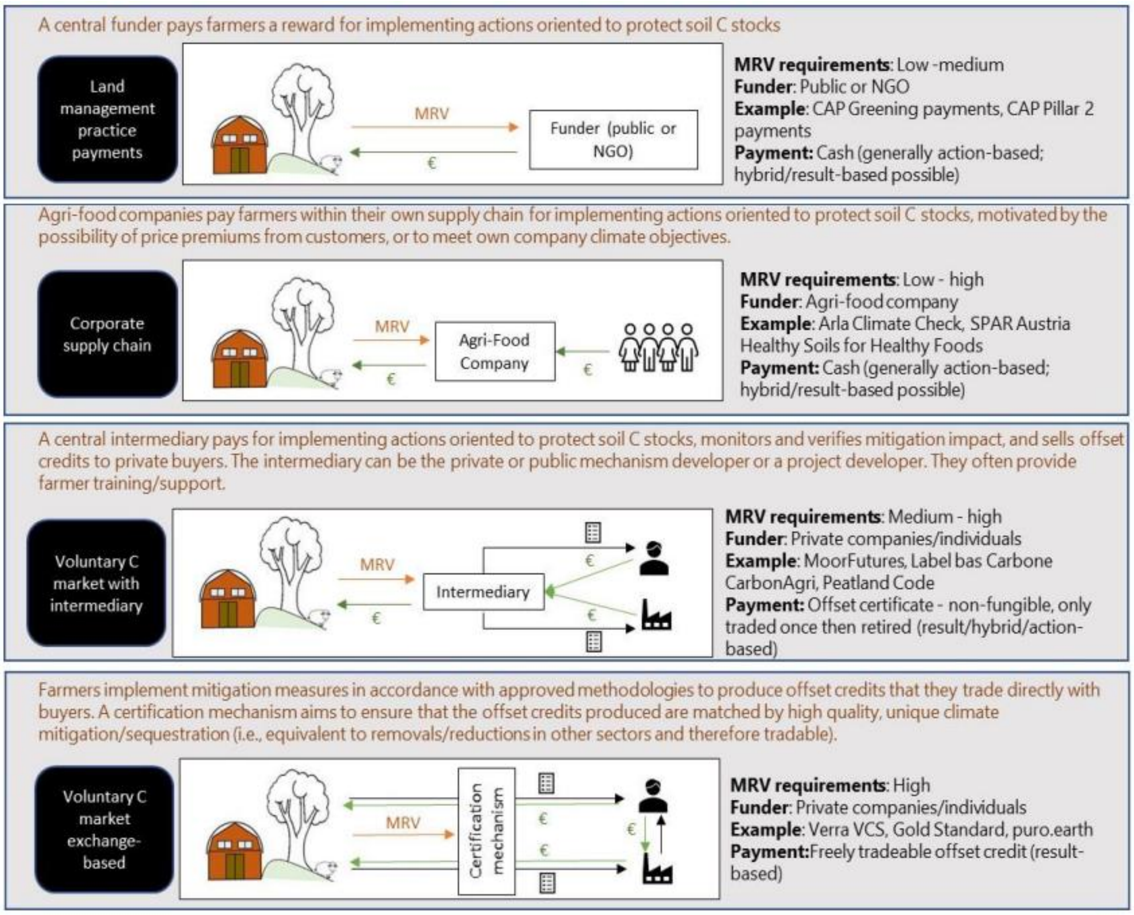

Figure 4: Models for carbon sequestration payments and mechanisms (Andrés, Doblas-Miranda, Rovira, Bonmatí, Ribas, Mattana, & Romanyà 2022, 78)

2.4 Sustainability and business models

This chapter provides insight into sustainability and the planetary boundaries, sustainable development in general as well as sustainable business model creation. I examine what are the main drivers for creating new businesses with a focus on sustainability aspects and what kind of benefits are there to be established when taking different aspects of sustainability into account when creating and developing business models.

2.4.1 Sustainable development

The definition of sustainable development originates from the Brundtland report published by the United Nations in 1987. Sustainable development can be described as actions – such as innovation and development patterns, consumption, and production of goods – that meet the current human needs without hindering the futures generations' ability to meet theirs. (Brundtland 1987, 16). Sustainable development can be seen comprising from three different pillars which are environmental, economic, and social sustainability. Often a fourth pillar is considered as well, which consists of a cultural or human centric viewpoint. The fourth pillar is also often linked with the social sustainability pillar. (Savelyeva & Douglas 2017, 219; Future Learn 2017; Ympäristöministeriö B)

Environmental sustainability means taking environmental aspects and the environmental carrying capacity into consideration when making decisions, to for example prevent loss of biodiversity and ensure a rational use of natural resources in a way that the environmental conditions would not deteriorate for future generations. Economic sustainability refers to financial stability and steady economic growth which in turn enables wellbeing. Mismanaging of assets and increasing debt does not support sustainable economic growth, which then affects also for example the social sustainability negatively. One of the main goals in social sustainability is to maintain and possibly improve the living conditions of future generations from the social perspective, which include for example improving equality as well as improving the accessibility of education globally. (Future Learn 2017; Ympäristöministeriö B)

In the year 2015 the United Nations launched their 2030 Agenda for Sustainable Development which built on the work United Nations had previously done for example through the Millenium Development Goals. The Millenium Development goals were established in 2000 and the target was to reduce extreme poverty by 2015. The Sustainable Development Goals consists of 17 different areas of development such as decent work and economic growth, clean water and sanitation and affordable and clean energy (Figure 5). (United Nations 2024)

Figure 5: The 17 UN Sustainable Development Goals (United Nations 2024)

When talking about sustainability and sustainable development, perhaps one of the most known frameworks related to sustainability in addition to the Sustainable Development Goals is the planetary boundaries originally formed by Rockström et. al. and which can be seen in Figure 6. The planetary boundaries consist of nine different aspects which are defined as atmospheric aerosol loading, rate of biodiversity loss, land system change, global freshwater use, biochemical flow boundary divided into nitrogen cycle and phosphorus cycle, stratospheric ozone depletion, ocean acidification, climate change and chemical pollution. According to the research group, the nine boundaries cover important global biogeochemical cycles, biophysical features of Earth, the three major circulation systems as well as aerosol loading and chemical pollution which are considered the two most critical features associated with anthropogenic global change. Biogeochemical cycles refer to the cycles of carbon, water, phosphorus, and nitrogen. Land systems, marine and terrestrial biodiversity are considered as the biophysical features of Earth, and these have a major contribution to the resilience of Earths self-regulatory capacity. Oceans systems, climate and stratosphere are the three major circulation systems. (Rockström, Steffen, Noone, Persson, Chapin, Lambin, Lenton, Scheffer, Folke, Schellnhuber, Nykvist, de Wit, Hughes, van der Leeuw, Rodhe, Sörlin, Snyder, Costanza, Svedin, Falkenmark, Karlberg, Corell, Fabry, Hansen, Walker, Liverman, Richardson, Crutzen & Foley 2009, 7).

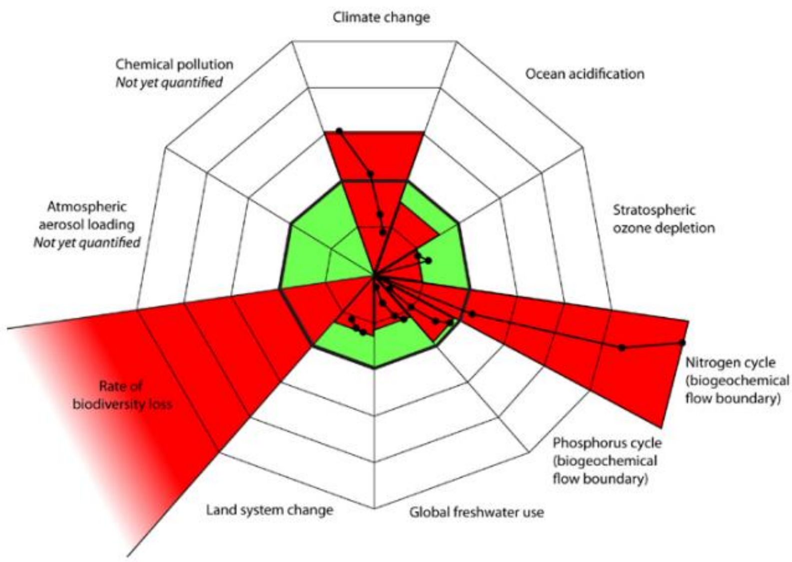

Figure 6: Planetary boundaries (Rockström et. al 2009, 23)

The model illustrates the nine different boundaries, and the center of the spiderweb-like figure represents the safe operating space highlighted in green. The research group had determined quantifiable control variables for all boundaries except chemical pollution and aerosol loading, which remained unquantified. The dots and lines between them represent the development of the control variable starting from 1950 to present. From figure 6 it can be seen that at the time the research was made, three boundary levels were already exceeded. Human behavior and actions that affect the Earth system - such as deforestation and its direct and indirect effects – are actions that affect the control variables negatively and thus result in exceeding the safe operating space of the boundary. The boundaries can also be interlinked in a way, that when a certain boundary is exceeded, it can influence the control levels of other planetary boundaries. (Rockström et. al 2009, 18, 20 & 23)

An update on the boundaries was made in 2015 by a research group consisting of mostly the same researchers as the original research group. At that time, their research determined that while the levels in stratospheric ozone depletion, climate change and ocean acidification as well as freshwater use had remained almost the same, some boundary levels such as land system change had expanded over the safe operating threshold, and the phosphorus cycle included in the biogeochemical flows had expanded past the boundary level of 2009. Some modifications to the boundaries were also made, for example chemical pollution boundary had been renamed into novel entities in the 2015 version, which refers to new substances, modified life forms and new forms of existing substances that may have potential to create unwanted effects on the biological and/or geophysical systems. Visualization of the updated boundaries can be seen in Figure 7. (Steffen, Richardson, Rockström, Cornell, Fetzer, Bennett, Biggs, Carpenter, de Vries, de Wit, Folke, Gerten, Heinke, Mace, Persson, Ramanathan, Reyers & Sörlin 2015, 8 & 9; Rockström et. al 2009, 23)

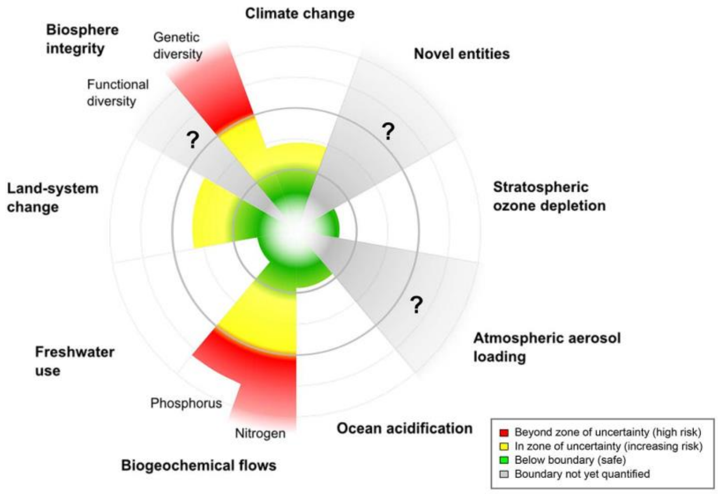

Figure 7: Planetary boundaries in 2015 (Steffen et. al., 8)

Kate Raworth based her own economic model – the Doughnut model – on the planetary boundaries as well originally in 2011 and in 2017 she published a book describing the economic model further. The center area of the doughnut is divided into twelve basic human needs and essential elements, such as water, housing, gender equality, health, and food. Raworth's model therefore also considers the social aspects of sustainability as well. While in Rockströms et. al. model, the center of the figure is seen as the safe operating space, in Raworths model, the center of the doughnut figure can be considered as a negative space, which visualizes the possible shortfalls of each inner element. The outer area provides similar ecological boundaries for the Earth system created by Rockström and his research group. The area of the doughnut itself – between the ecological ceiling and the social foundation - represents a similar safe operating space for humanity referred to in in planetary boundaries model, where the basic human needs are met in a sustainable way that does not create harm on the ecological boundaries. The visualization of Raworth's Doughnut model and its different boundary elements can be seen in Figure 8. (Raworth 2017, 45 & 51)

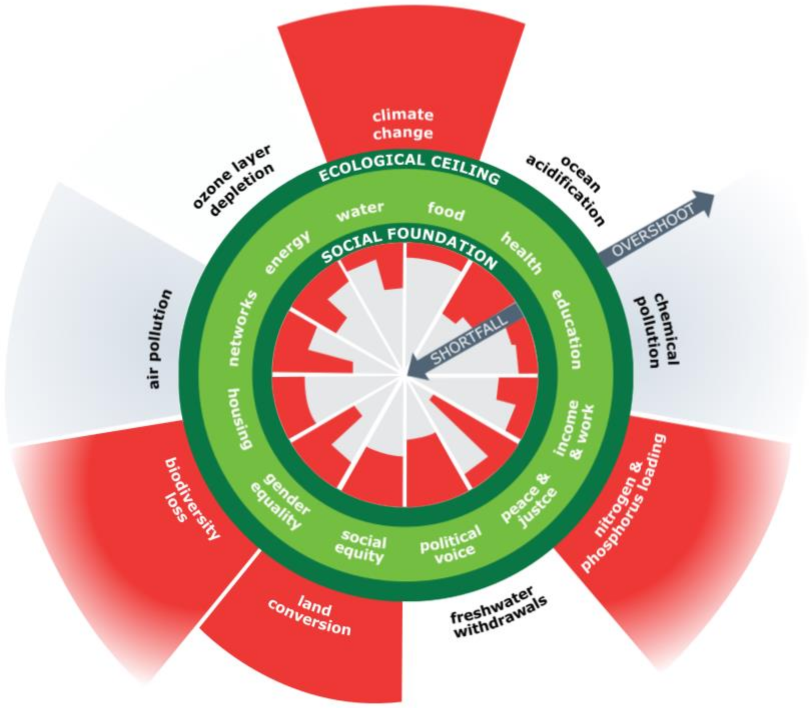

Figure 8: The Doughnut of social and planetary boundaries (Raworth 2017)

In May 2023 another update on the planetary boundaries was made by a research team led by Rockström. Figure 9 visualizes the latest version of the boundaries - which similarly as Raworths doughnut model - considers aspects of human wellbeing in addition to the previously emphasized earth system resilience. Red line indicates a safe boundary for the sector, blue line indicates the just line – meaning, that while it might be safe from earth system resilience perspective to reach the red boundary, it is not necessarily safe from the perspective of a just society. Green line indicates a boundary where the safe and just boundary are aligned. The small globe figure indicates the current situation of each sector, and green dotted circle is a boundary for the minimum safe level of access to basic human needs such as water, food and energy. (Rockström et. al 2023, 103-105)

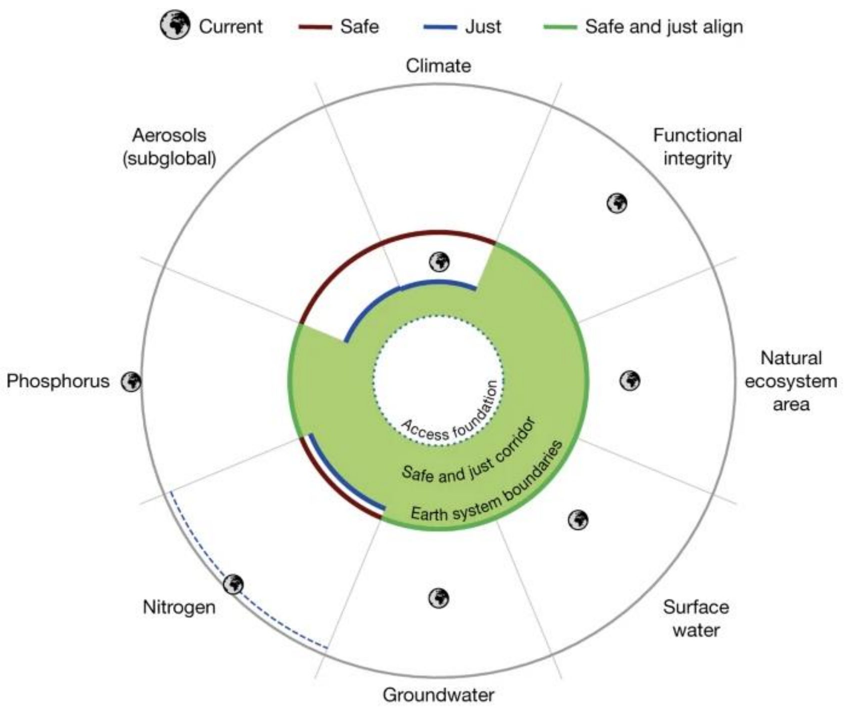

Figure 9: Safe and just earth system boundaries (Rockström et. al 2023, 104)

2.4.2 Business models

Business model can be seen consisting of three aspects:

1. Value proposition
2. Value creation and delivery system
3. Value capture

Value proposition refers to the product and service offering a company provides to bring value to its customers. The key element of the value proposition is also the strategic viewpoint of the company which can be summarized in the following question – what will make the company's offering to the market more appealing to customers compared to the competitive companies? Value creation and delivery systems refers to the way in which company has organized its processes and resources to create and deliver value to its customers in a competitive way (Richardson 2005, 12-16).

Value capture can be seen consisting of two elements – revenue model and the economic model – where the revenue model focuses on describing the revenue that a company receives in exchange from the value it has provided to its customers, and the economic model can be considered to include also other financial aspects of a company that are linked to the value creation, such as operating costs and margins. In short, value capture refers to the way a company generates profit and revenue from the delivery of its value proposition. (Baldassarre, Calabretta, Bocken & Jaskiewicz 2017, 176; Richardson 2005, 12-16)

A business model can be seen as a strategic asset of a company. It is the architecture which elaborates clearly on the three above-mentioned aspects. It consists of understanding the customers' needs and their ability and willingness to pay for the service or product, explains the ways which the company delivers the value to their customers and the mechanisms and processes along the value chain which provide sufficient profit to the company in return. (Schaltegger, Hansen & Lüdeke-Freund 2016, 4-5; Niemimaa, Järveläinen, Heikkilä & Heikkilä 2019, 209)

2.4.3 Sustainable business development and innovation

Traditionally business model development has focused on the value creation and financial gains of the company, but in the current social, economic, and ecological environment, the need to consider different aspects of sustainability is not only in certain aspects required by legislation but also supported by research which indicates a correlation between a good environmental, social and governance (abbreviation ESG) metrics score and company's value as well as profitability. One of the reasons behind this could be those efforts towards good environmental, social and governance practices create trust in the company's overall management and business strategy. It can be seen as a sign that the company is able to build resilience by considering the operative environment and its different stakeholders more thoroughly in order to create and preserve value. This in turn translates into positive returns and financial credibility from an investor's perspective. (Aydoğmuş, Gülay & Ergun 2022, 125; Dahlgaard & Anninos 2022, 482)

Integrating the three pillars of sustainability - environmental, economic, social - with business development and innovation can be difficult since it requires a more comprehensive approach to business model development and view on value creation. It requires a better understanding of all stakeholders involved as well as a wider understanding of what value means to those different stakeholders. When creating sustainable business models, collaborating with a wide range of stakeholders can be beneficial to gain more acceptance, support, and commitment related to sustainable innovation. (Baldassare et. al. 2017, 184; Matos & Silvestre 2013, 62-63)

Challenges related to sustainable business development and innovation are the lack of in-depth knowledge related to sustainability aspects and the ability to translate the desired sustainable goals into products and services that provide customer value. To maintain an economically viable sustainable business, a company is required to manage and adapt shifts in sustainability requirements as well as customer demands. (Keskin, Diehl & Molenaar 2013, 58)

Baldassarre et al. (2017, 183) present in their research a model for sustainable value proposition for companies (Figure 10). The model combines sustainable value proposition and user driven innovation, to achieve a more comprehensive understanding on the topic in question and methods to refine their offering to cater to the needs of their targeted customers but also to maintain the development within a sustainability framework. In the model, sustainability value proposition and design consist of three interlinked building blocks. Sustainable value proposition consists of stakeholder network, sustainability problem and product and/or service. The design aspect consists of talking, thinking, and testing. The blocks are interlinked, so that the first step is to talk to the stakeholder network and the best results are achieved usually by conversational interviews and co-creation session (Baldassarre et. al. 2017, 183-184).

Based on the data collected from the stakeholder network, the value proposition process continues to the second step which is thinking about the problem from the sustainability perspective by taking advantage the feedback received and information gathered in the previous step. This can be done with the help of various innovative tools such as brainstorming and problem reframing. Once the second step has been finalized to a certain extent, it is time to move forward to testing the product or service idea that has been worked on. Similarly, as in any product and service design process, it is recommended to test out the minimum viable product to quickly assess which features are delivering the assumed value and which are not, in order to proceed to correct and refine the product or service to match the customer requirements as much as possible and this way provide the highest value to the customers. (Baldassarre et. al. 2017, 183-184).

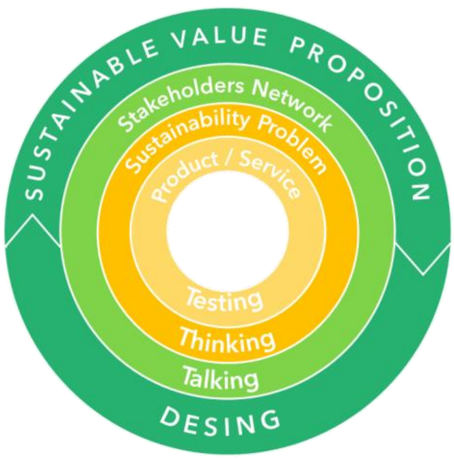

Figure 10: Sustainable value proposition, based on Baldassaare et. al. 2017, 183

2.5 Synthesis for agrivoltaics business development model

Agrivoltaics business development can be seen as a sustainable business development, when considering the aspect that it enables efficient land use – renewable energy production is done simultaneously with food production while also providing financial benefits for farmers. Agrivoltaic systems can affect the natural landscapes drastically which can be problematic as well. There are also many open questions still related to, for example land restoration and effects on the growing conditions of crops as well as soil conditions, which require further examination. Farmers and landowners' opinions towards agrivoltaics as well as the characteristics of the farms can affect their adaptability towards these types of business opportunities.

Sustainable business development considers not only the financial benefits of business opportunities but expands the viewpoint also towards the different pillars of sustainability from the perspective of different stakeholders and due to this sustainable value proposition model (Figure 10) is a good, simplified framework that can be used to help create the innovation model. The financial benefits for farmers can be seen as promoting the cultural and social sustainability of farmers and thriving rural areas and renewable energy production together with food production can be seen as balancing between the social foundation and ecological ceiling when considering the doughnut framework by Kate Raworth in Figure 8.

3 Research methodology and execution

Goal of this thesis was to create a preliminary innovation model for agrivoltaics business development in Finland. This was approached by examining the characteristics and opinions of farmers related to possible agrivoltaic systems gathered via questionnaire and combined with the literary review related to different relevant themes around agrivoltaic systems, such as agriculture in Finland and energy transition as well as sustainable business models in order to create a preliminary guideline and key elements for agrivoltaics business development.

The literary review was chosen as a research methodology since it provides insight into the different themes that can influence the agrivoltaics business development. Energy transition and carbon neutrality goals put emphasis on renewable energy in all sectors of society, including agriculture, and also the current state of agriculture in Finland can provide some insight on whether the agricultural sector is open and willing to look into new and innovative solutions to combine their current business operations with such systems. There is a strong structural change currently happening in the agricultural sector, since one third of the agricultural land currently is owned by people aged between 55 – 64. It raises questions about what will happen to the land after this group retires – will the land be rented out to other functioning farms making their operations bigger and if so, how will they manage financially. Sustainability and the impact of things businesses do in the current state of the world is no longer considered a competitive advantage but rather a necessity of a successful business operation. Therefore, the literary review also provides information regarding sustainable business development.

The purpose of the questionnaire was to provide additional insight on farmers' and landowners opinions as well as characteristics to see, if there is a recognizable pattern of early adaptation regarding agrivoltaics, which then could be taken into consideration when constructing the innovation model. Information gathering was done via a questionnaire that was created with Microsoft Forms that was available for Laurea students, and only the creator of the questionnaire had access to the results of the questionnaire. The research is both quantitative and qualitative (Tilastokeskus A, Tilastokeskus B). The quantitative questions focus on characteristics of the land, farm operations and landowner and ask if landowners were already familiar with the term agrivoltaics, if they had been approached by energy companies regarding land acquisition previously and whether they were interested in renting out their land solely for photovoltaics systems or for agrivoltaic systems that would enable them to continue their operation. The questions had readymade options where the respondent could choose from, and some of these included a free text box to further clarify their response. The qualitative questions focus on finding out more thoroughly about the factors that the landowner might find value if they were to rent out their farmland for agrivoltaics system and how they would think the local community would react to agrivoltaic systems compared to traditional photovoltaic system. Full list of questions can be seen in Appendix 1.

The focus group of the questionnaire was landowners which included both active farmers as well as landowners who themselves are not active farmers but own land and rent it out. Microsoft Forms automatically created a link to the questionnaire and the link was posted to different Facebook groups which included: Monipuoliset ja tuottavat pientilat; Maatiaisviljat – Lantkorn; Luomuviljelijät; Maanviljelijät and contact person listed in the webpages of the The Central Union of Agricultural Producers and Forest Owners (Maa- ja metsätaloustuottajain Keskusliitto, MTK) and its youth association were contacted via email and asked to forward the link to the questionnaire in their mailing lists if possible. The questionnaire was open during 3.3.2024 – 31.3.2024, and the approximately time was for responding was estimated to be 10-15 minutes. No personal information was gathered in the questionnaire and the questions were constructed in a way that anonymity of the respondents was enabled. The use of the results in this thesis was communicated in the introduction message to of the questionnaire, so respondents were aware that the results would be used as a part of this thesis and the results were stored only while the thesis process was ongoing. The questions where in

Finnish and have been translated to English for this thesis. There were altogether 25 individual participants in the questionnaire. Based on the literary review and the responses received in the questionnaire, a preliminary framework for agrivoltaics business development was created based on the sustainable value proposition framework presented in Figure 10 and four key elements to address in the future developments were identified.

4 Results and analysis

In the following chapter I go through the answers gathered with the questionnaire and analyze the results. The chapters are constructed so that questions and the results are grouped based on the type of the question, whether it is related to the characteristics of the farmer or landowner and the land itself, photovoltaics and agrivoltaic systems in general and the qualitative questions which allowed the respondents to describe their views more freely on the questions.

4.1 Characteristics of the landowner and farm operations

The first question was related to the current use of the land. 18 of the respondents are currently active farmers themselves, 5 own lands but it is currently rented out and 2 of the respondents were both active farmers themselves and rented out part of the land they owned. (Figure 11)

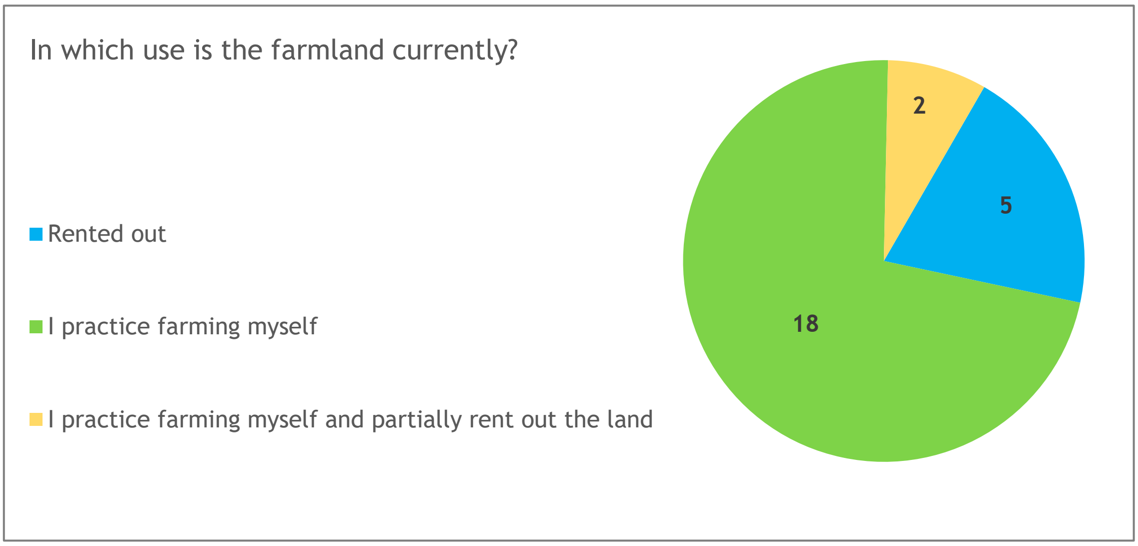

Figure 11: Current use of farmland, n = 25

The second question was related to the location of the location of the farmland. The questionnaire was able to reach out landowners from different parts of Finland. There were 25 individual respondents, but one respondent owned landed in multiple locations. (Figure 12)

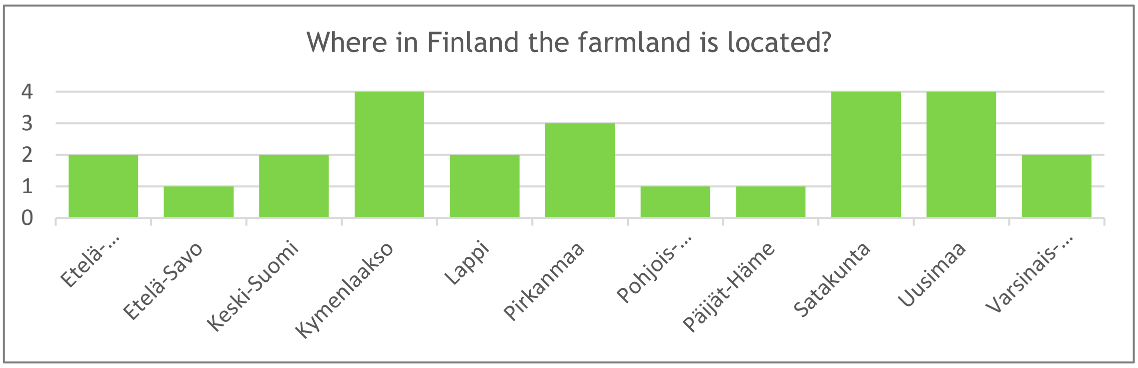

Figure 12: Location of land, n = 25

One of the questions was related to the form of operation. In agriculture, farmers can farm by themselves or as part of different kinds of agricultural enterprise, which then affects how the operations are run. 14 of the respondents' farmed by themselves, and 6 farmed as part of an enterprise. 4 of the respondents rent out the land so they do not farm nor are they a part of any enterprise. One respondent explained in the free text field available in the question that their land was mostly rented, and the farming operation was small scale. (Figure 13)

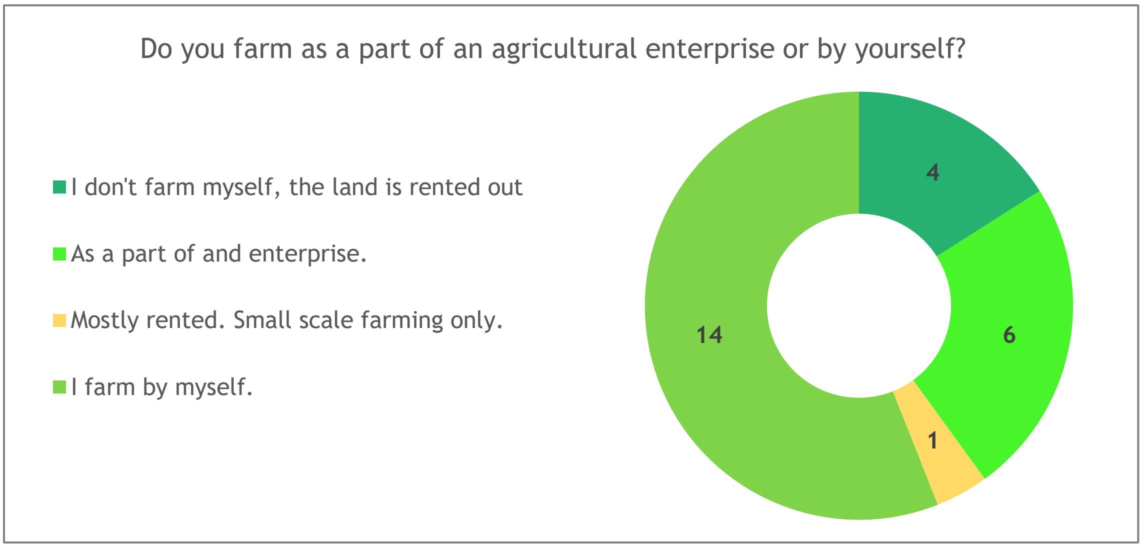

Figure 13: Farming operation type, n = 25

Question number four was to determine if the land is rented out, when was the last time the land was farmed within the family. Most of the respondents (15) were landowners who farmed the land themselves, but 3 people responded that it was farmed within the family five or less years ago, 6-10 years ago and over 10 years ago both received 2 respondents each. (Figure 14)

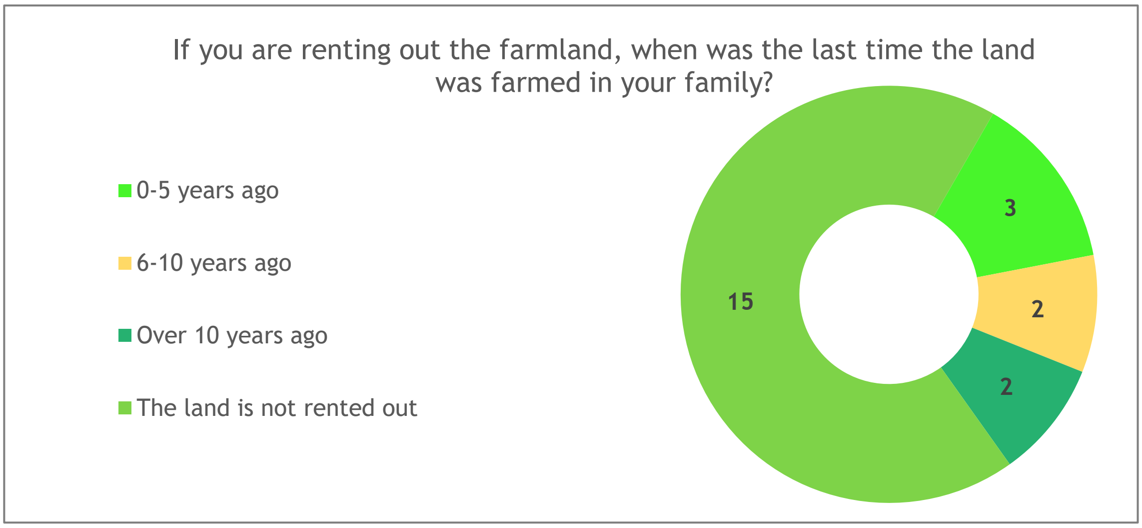

Figure 14: Farming within the family, n = 22

The fifth question was related to the availability of a possible successor to the farm operation. As discussed in chapter 4.1 the average age of farmers in 2022 were 54 years. Without a suitable successor, continuing the farming operation is not possible, and the landowner will then have the option to either sell or rent out the land or look for other opportunities to handle the asset. 12 of the respondents did not yet have any successor planned out, 8 did have and 5 responded that they currently rent out the land, so there is no farming operation to pass on to in the traditional sense. (Figure15)

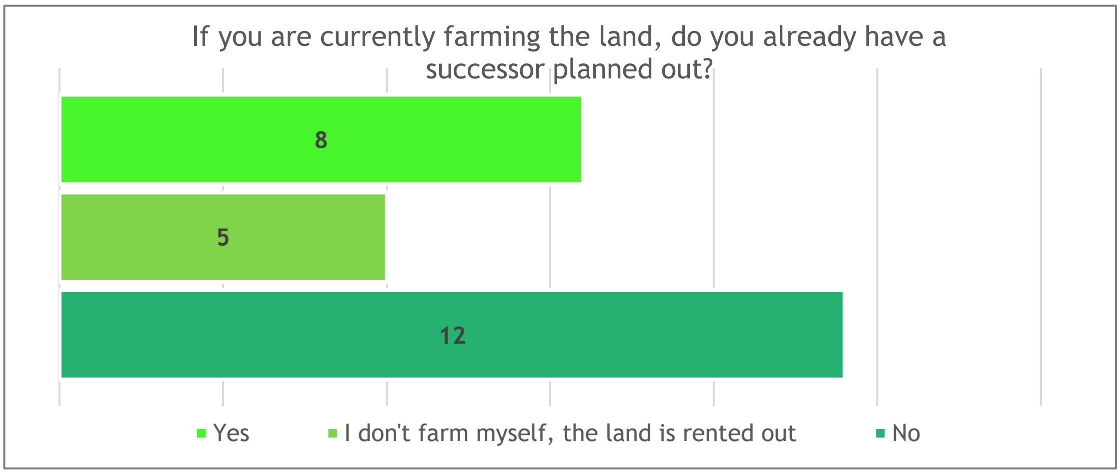

Figure 15: Availability of a successor, n = 25

The sixth question was related to other possible income streams in addition to the farming operation. Altogether 14 respondents, which is over half of the overall number of respondents, mentioned that they also do other work, which is not directly related to the farming operation, of which one did both machinery contracting as well as agricultural consulting. (Figure 16)

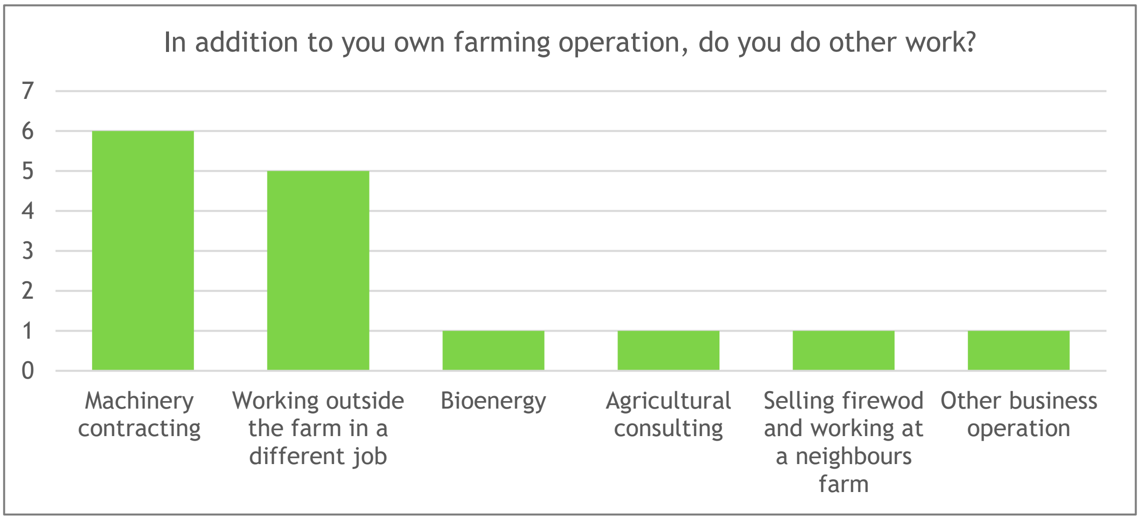

Figure 16: Other income streams, n = 14

Question number seven was related to the age of the landowners. The majority of the respondents were in the age group 31 – 40 years, and then the age groups below 30, 41 to 50 years and over 61 years had 5 respondents each and 3 respondents where in the age group 51 – 60 years. (Figure 17)

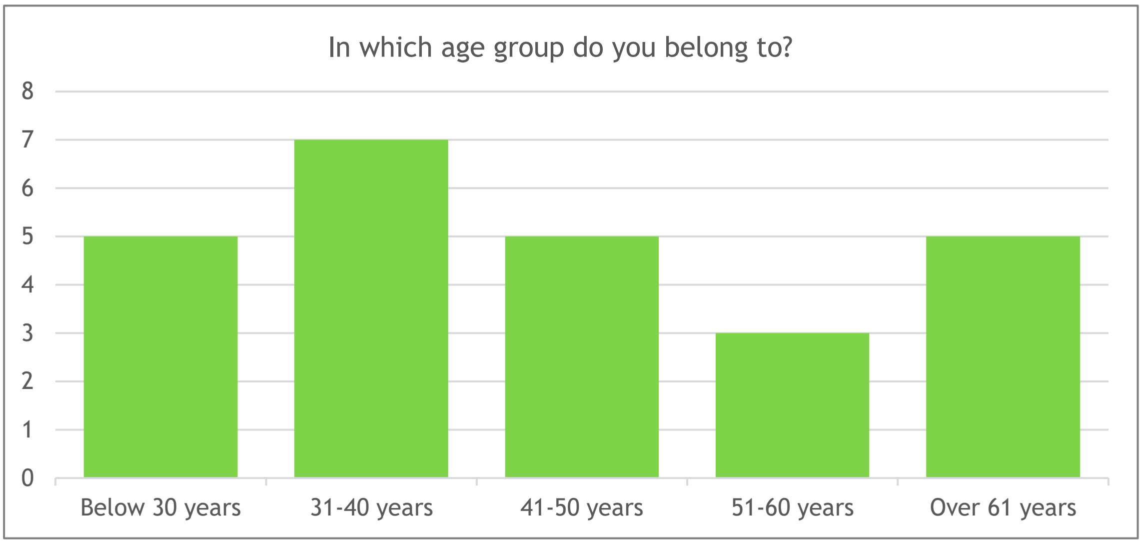

Figure 17: Age of respondents, n = 25

4.2 Opinions on photovoltaics and agrivoltaics

Question number eight inquired about the knowledge of the term “agrivoltaics”, “agri-PV” or “maatalousaurinkosähkö”. Most of the respondents (18) had not heard the term before, but 7 were already familiar with it. (Figure 18)

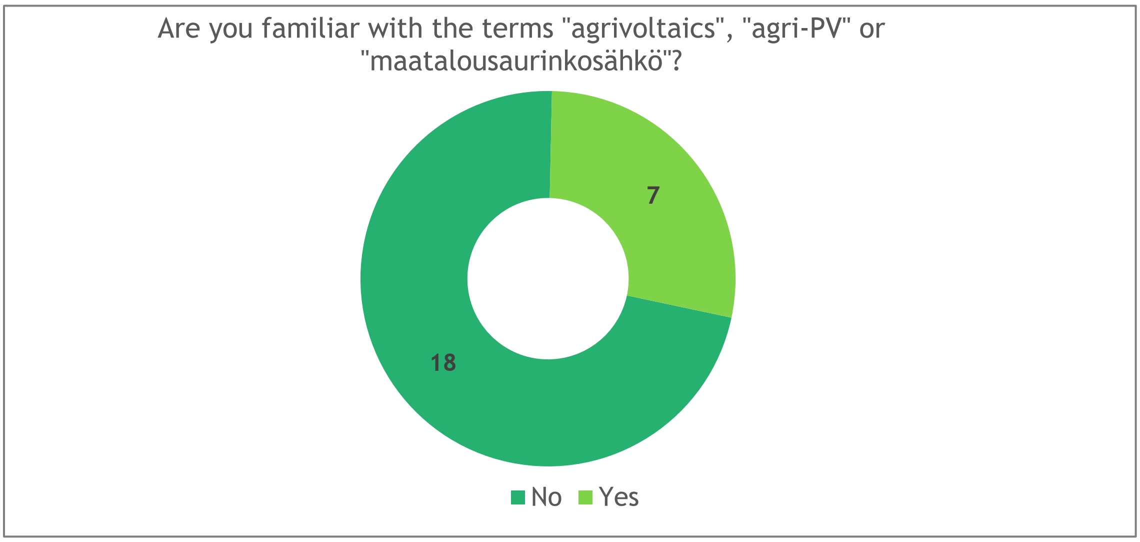

Figure 18: Familiarity with agrivoltaics, n = 25

When asked if the landowners had been approached by companies related to land acquisition for renewable energy construction, 15 responded no and 10 responded yes. (Figure 19)

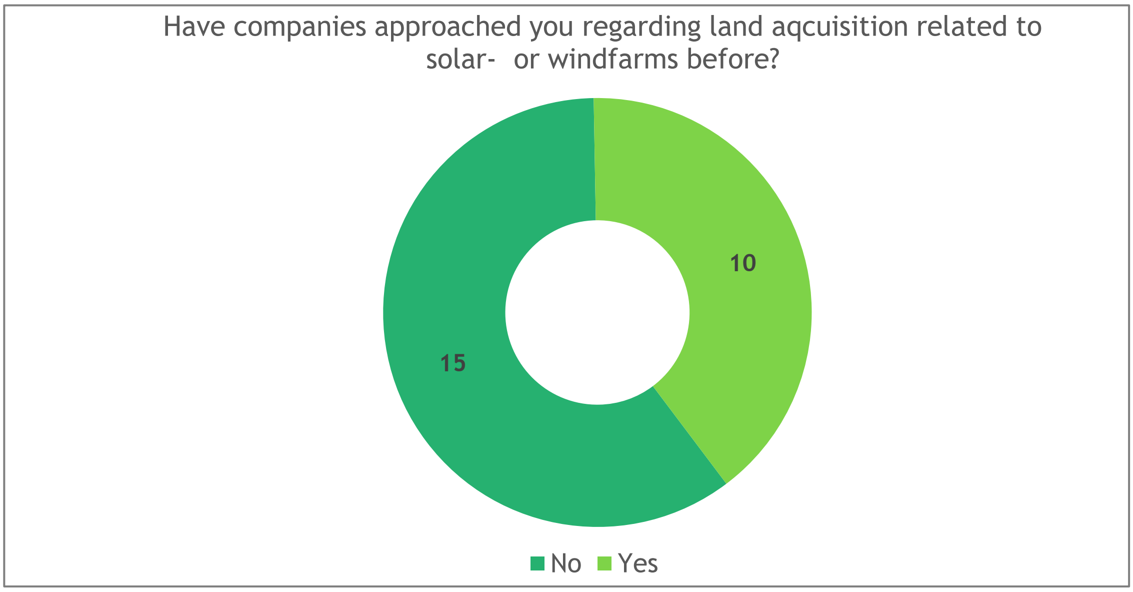

Figure 19: Earlier contacts related to land acquisition regarding renewable energy, n = 25

Question number ten asked if the respondents would be interested in renting out their land for photovoltaic systems, and the results were quite even: 13 said no and 12 said yes. (Figure 20)

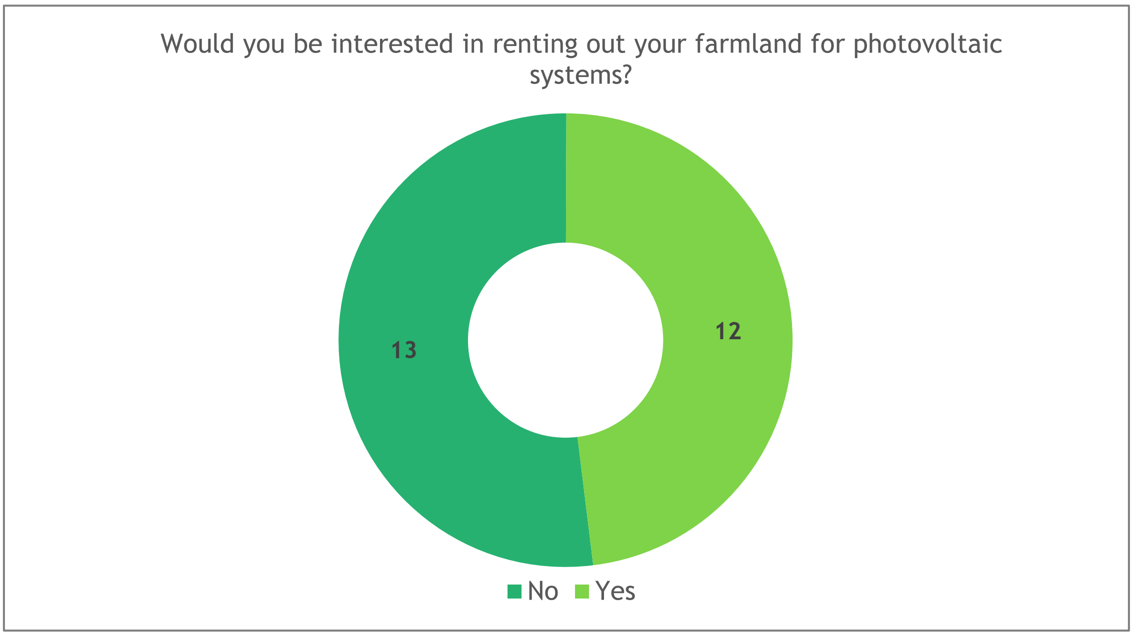

Figure 20: Interest in renting out land for photovoltaic systems, n = 25

When asked if the respondents would be interested in renting out the land for photovoltaic system if it was possible to still to operate farm in traditional farming in addition to energy production, a clear majority answered yes. Altogether 19 were interested in this option, while 6 were not. (Figure 21)

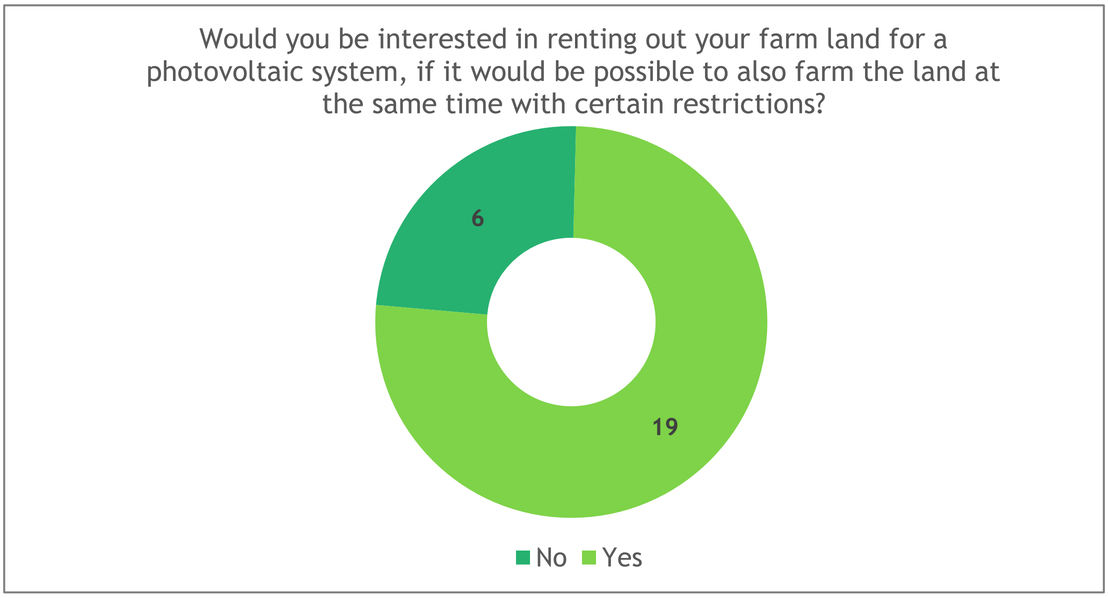

Figure 21: Interest in renting out land for agrivoltaic systems, n = 25

When looking into the respondents age groups of those landowners which responded “Yes” to the question would they be interested in photovoltaic system if they would be able to use the land also in farming operations as shown in figure 21, there were five respondents below 30 who answered “Yes”, and no one in this age group answered “No”. Five respondents between 31 – 40 years old also answered “Yes”, while two answered “No”. In the age group 41 – 50 there were three “Yes” responses and two “No” responses. In 51 – 60 group two respondents said “Yes” while one said “No”, and in the over 61-year-old group four respondents said “Yes” and one said “No”. (Table 1)

	YES	NO
Below 30 years	5	0
31-40 years	5	2
41-50 years	3	2
51-60 years	2	1
Over 61 years	4	1

Table 1: Age of landowners who would be interested in agrivoltaic systems, n = 25

Regarding the ideal time frame for renting the land out for agrivoltaics system, 12 of the respondents answered that 11 – 20 years would be the most suitable. 6 answered that 21 – 30 years would be ideal for them, and 5% responded considered less than 10 years most ideal. 1 was OK with 31 – 40-year rental period and 1 was OK with over 41-year rental period. (Figure 22)

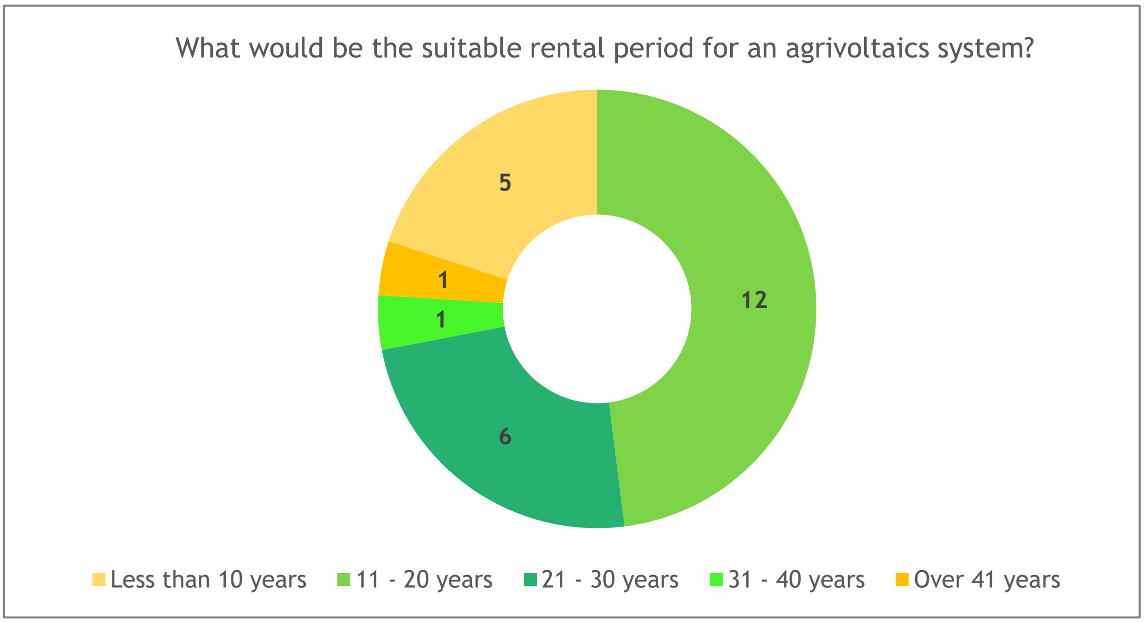

Figure 22: Suitable rental period, n = 25

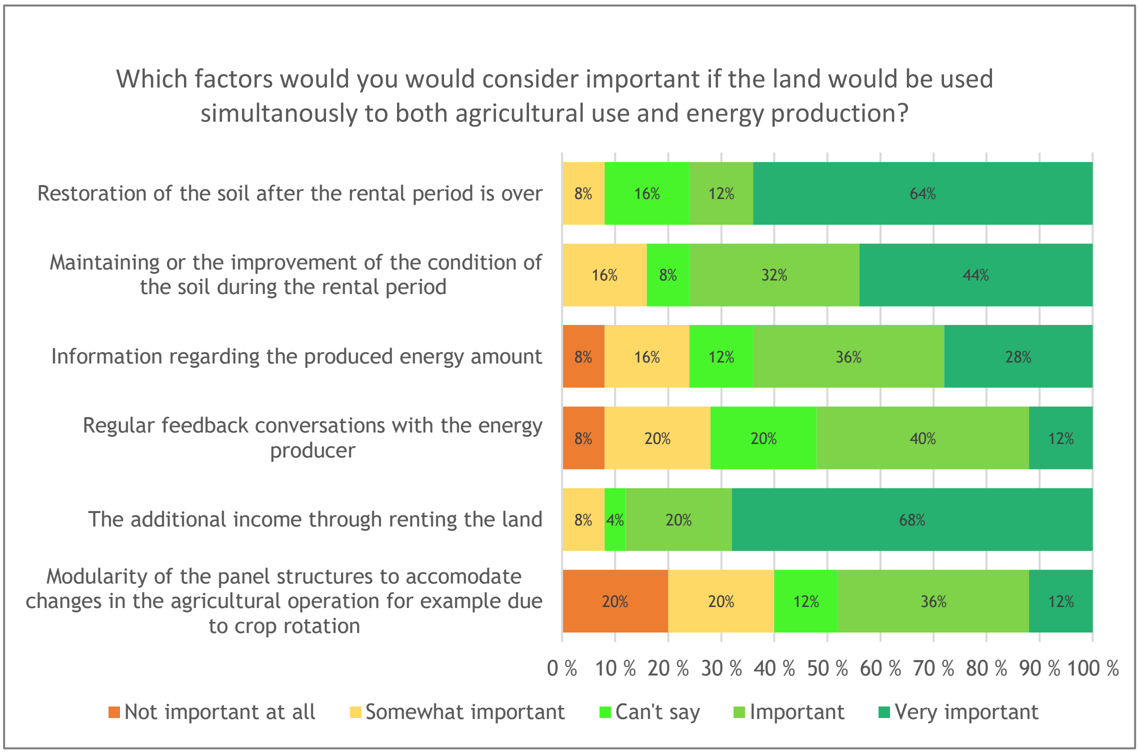

Figure 23. Which factors landowners would consider important if their land would be used in both agricultural business as well as energy production, n = 25

When asked which factors farmers would consider important if their land would be used both for agricultural purpose as well as energy production, most landowners valued the additional income as one of the most important factors with 68 % answering that this would be very important. The second most important factor was considered soil restoration after the rental period with 64 % considering this very important. Maintaining or improving the soil conditions during the rental period was also regarded mostly important (32 %) or very important (44 %). Landowners also mostly considered the information regarding the amount of produced energy important to them, with 36 & of respondents considering this as important and 28 % considering it very important. (Figure 23)

Modularity of the panel structures was one of options that received the most “Not important at all” votes from all the factors listed in the question – 20 % of the respondents answered that this was not important to them, however 20 % considered this somewhat important, 36 % considered this important and 12 % considered it very important. (Figure 23)

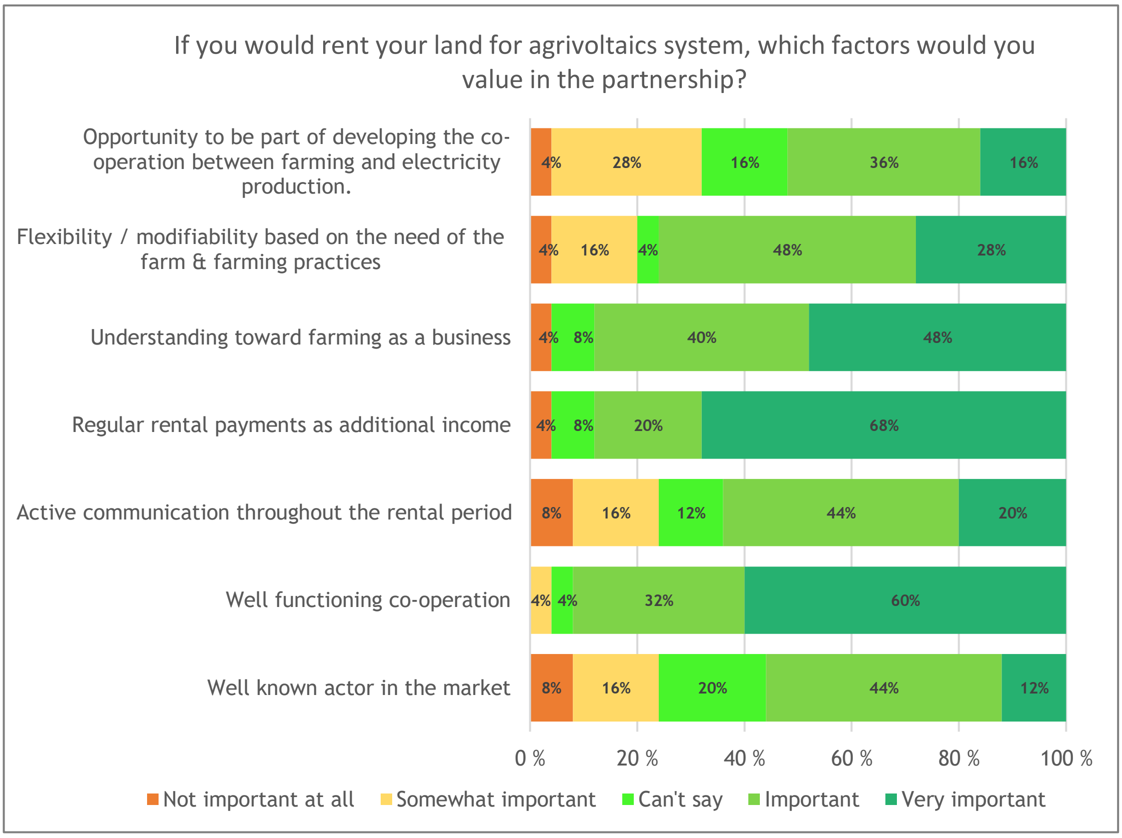

Figure 24: Factors landowners would value in the partnership between an agrivoltaics system provider and operator, n = 25

When asked which factors landowners would value in the partnership between the parties that rents the land for energy production, 68 % of respondents considered the enabling of regular rental payments as "Very important" and 20 % considered this "Important". Wel-functioning so-operation was also considered as a valued factor with 60 % respondents considering this "Very important" and 32 % considering it "Important". Understanding farming as a business was also valued very high, with 48 % considering this "Very important" and 40 % considering this "Important". (Figure 24)

4.3 Qualitative questions

When asked with an open question which factors landowners would consider worrisome if their land would be used both in agriculture as well as energy production, the answer varied from bureaucracy, permit matters as well as farming subsidy related topics to more practical issues such as how the land would be restored after the rental period and how farming equipment's would be able to fit between the panel constructions. Answers listed in Table 2.

What would be worrisome factors if the land was used both in agriculture and in energy production?
Bureacracy
Maintenance or repair during the growing season
How to fit among the panels with large machines
Working with machines near the structures, risk of collision. Possible management issues with the company.
Who dismantles the facility after its lifecycle? I don't trust that, for example, in 20-30 years, things will go smoothly.
Who will take care of the mess when the panels fall apart.
Permit matters. Things related to electricity transmission, power lines, etc.
Mainly maintaining the fields status as arable land and eligible for farming subsidies.
There would be problems regarding agricultural subsidies and in practice simultaneous use is not possible in the same area.
Land pollution? How would organic farming be possible, or would it even be possible to farm organically?
Reasonable use of land
Is it possible to get farming subsidies
The challenges of harvesting/grazing. How do I get the most out of the field area?
The biggest question is the possible deterioration of the drainage pipes condition and how to prepare for it.
Room for machinery
Loss of subsidies, deterioration of the land's growth condition, continuation of organic farming
Shading

Table 2: Worrisome factors related to agrivoltaics n = 17

One of the questions were also related to how the landowners would consider their neighbors opinions towards an agrivoltaics system compared to a traditional photovoltaic system, where the whole land area would be allocated to the photovoltaic system. The answers varied from negative to more positive, and there was not a clear consensus on the fact that the response would be either fully negative or fully positive. Answers can be seen in Table 3.

How would you think the surrounding neighbors would relate to an agrivoltaic systems compared to a regular photovoltaic system?
It would raise interest.
Perhaps negatively. Issues regarding protected landscape areas and with the county.
Perhaps more positively.
No difference
I don't know
I don't know
With suspicion
Well.
Moderately.
More positively.
More positively.
Neighbors' complaints on the negative effect of the landscape.
My own attitude would be a bit milder; I could possibly listen to the offer/presentation. The land under the transmission lines makes me wonder if a project would be planned nearby.
Mixed reception
The attitude would be better if agricultural use continued side by side
Probably initially negatively
They would like it if it meant not spreading manure on the fields.
I would think that everyone would find it accurate/favorable to strive for the continuation of agricultural use
Probably more positively
Negatively

Table 3: Opinions of surrounding neighbors, n = 20

The respondents were also given an option to add more important factors that they would consider valuable in the partnership between the agrivoltaics system provided in addition to the ones asked in question number 16 and which answers are presented in the Figure 24. Transparency regarding contract terms and information was considered as important factors, as well as the certainty of the continuation and reliability of the operation was valued as well. Also, the idea of using electricity in the farming operation was brought up as well. The length of the rental periods was considered too long, and one respondent was interested to see if there already were positive experiences from a farmer’s perspective available. Impact on farming subsidies was raised here as well. All answers can be found in Table 4.

In addition to factors presented in question 16, is there any other factors you would want to add as important when it comes to the co-operation?
Transparency and flow of information
Transparency regarding contract terms
Certainty of the project's implementation, collateral, use after the contract
At what price can you get electricity instead.
Why should a farm rent the land to others for electricity generation. Wouldn't it make more sense for the farm itself to own the panels.
Are there already positive experiences of the arrangement in question from the farmer's point of view? Impact on agricultural subsidies.
Guarantee coverage, which ensures that the rental income is received during the notice period and the costs of restoration are covered
A serious and reliable company, so that the cooperation company would not immediately go bankrupt.
The rental times are too long.
Choosing a partner is like choosing a wife -- 40 years of common interest and still the underdog.

Table 4: Other important factors when considering partnerships, n = 10

In the end of the questionnaire landowners were asked if there was anything they would like to know more about agrivoltaics if they would consider such systems to be installed in their land. While some answered that they were not interested and therefore did not require further information, others raised concerns and questions regarding land restoration, cultivation restrictions, landscape aspects and subsidies. Also, how disruptions would be handled during operation and growing season was raised as one important factor and contract models were answered. Skepticism regarding agrivoltaics in general was raised, and the idea of building photovoltaic systems to wastelands was considered a more viable option than focusing on building them on active farmlands. All answers can be found in table 5.

Is there any particular aspects you would want more information regarding agrivoltaics systems?
I would not like to rent fields but invest myself. I would also be interested in drying the chopped wood with electricity when electricity is cheap.
Nothing, I'm not interested
I am not the target group when I have thought about transferring the lands to nature conservation.
Restoration, receivables, risks
The first question is the lack of market information (rent e/ha), then operational experiences.
Disruptive situations and their treatment during the growing season
Organic grain cultivation technology between the panels
Landscape aspects, work safety, returning the area to agricultural use at the end of the rental period.
How would the panels affect the cultivation possibilities? What could be cultivated and what not?
Restoration guarantees at the end of the contract period
Contract models
I am very skeptical that such an operation would go smoothly. There are certainly wastelands on which power plants can be established, and when they are functional and that the area remains clean and good for nature, then we could start planning the establishment of solar power plants on farmland.
Subsidy policies.

Table 5: Additional information needs, n = 13

4.4 Analyzing results

The number of respondents was not that high, which then in turn hinder the credibility of the results themselves, but despite this the results still give indication that agrivoltaic systems are found as more interesting option when compared to traditional photovoltaic systems from the perspective of the landowner who will rent the land out to energy production. The questionnaire also was constructed so that it would gather information regarding landowner characteristics, such as age group, location, whether the land was currently farmed by the landowner themselves or if they were rented out. As discussed in chapter 2.1.4, both the farms and farmers characteristics can have an effect whether they are considered early adopters or not, but since the number of responses was so low, no clear and credible patterns can be drawn based on the answers as to what type of characteristics would be present in a landowner that would be willing to implement agrivoltaics as part of their farming operations and what type of landowner would not.

There were also questions related to when was the last time the land was farmed within the family, if the land was currently being rented out and if there was someone already in mind to continue the operation after the current farmer would retire. These questions were asked to see if there was a link between the willingness to proceed with agrivoltaics or traditional photovoltaics with landowners who currently do not farm the land themselves or who do not have anyone in mind to continue the farming operation in the future, but the results did not give a clear correlation regarding this. However, as mentioned earlier, due to the low number of responses it is not possible to clearly state if an actual correlation exists or not. As discusses in chapter 2.3.1, the average age of active farmers in 2022 was 54, so the in the future more and more farmers will retire, which then raises the question will those farms have successor and in what capacity, or will there be more and more land available to be rented out to either other farms or possible to other uses, which could in the future include various carbon market solutions as mentioned in chapter 2.3.3. or energy use in some form.

The additional income that the agrivoltaics system would provide to the farming operation was raised as a very important factor, which can be seen from Figure 23 and Figure 24. This is understandable also in general since when operating a business, profit is generally the key element, but especially in farming since currently the financial returns in farming are not very high as mentioned in chapter 2.3.1. while the risks and investment needs in turn are. In Table 2 where the open-ended question result related to the worrisome factors was asked concern regarding possible applicability to farming subsidies was also raised, and the subsidy policies related to this was also raised as something the responders would want more information on as can be seen in Table 5. In the answers to the open ended questions which can be seen in Tables 2, 4 and 5 a lot of the answers were related to how the land quality as agricultural land would be ensured and how the agricultural operation would be viable together with the panels: how would the maintenance of the panels be handled during growing season and if the machines used in agriculture would fit between the panels as well as how the condition of the drainage pipes would be considered in this type of co-operation. The answers indicate that since there are a lot of aspects that farmers need to consider when running their farming operation profitably, such as soil conditions, crop rotation and suitable varieties for different types of land, decisions on which type of machinery farmer will invest in based on their operational needs, restrictions and guidelines from different authorities regarding subsidies and farming operations in general, implementing agrivoltaic systems would need a careful consideration and co-operation from multiple different stakeholders.

4.5 Innovation model for agrivoltaics business development

The construction of the innovation model will follow the principles discussed in chapter 2.4.3 and visualized in Figure 10 and also highlight four major topics to consider with the stakeholder network in order to determine an environmentally, economically and socially beneficial business model for all parties involved. Following the framework visualized in Figure 10, the sustainable business development process is defined through sustainable value proposition, which is discussed through with stakeholder network, focusing on a certain sustainability problem which then can create a product or a service that can address the issue and which can then be tested. Regarding the agrivoltaic business development, based on the literary review and responses gathered through the questionnaire, a following value proposition model was created in order to clarify the value proposition, sustainability problem and stakeholder network (Figure 25):

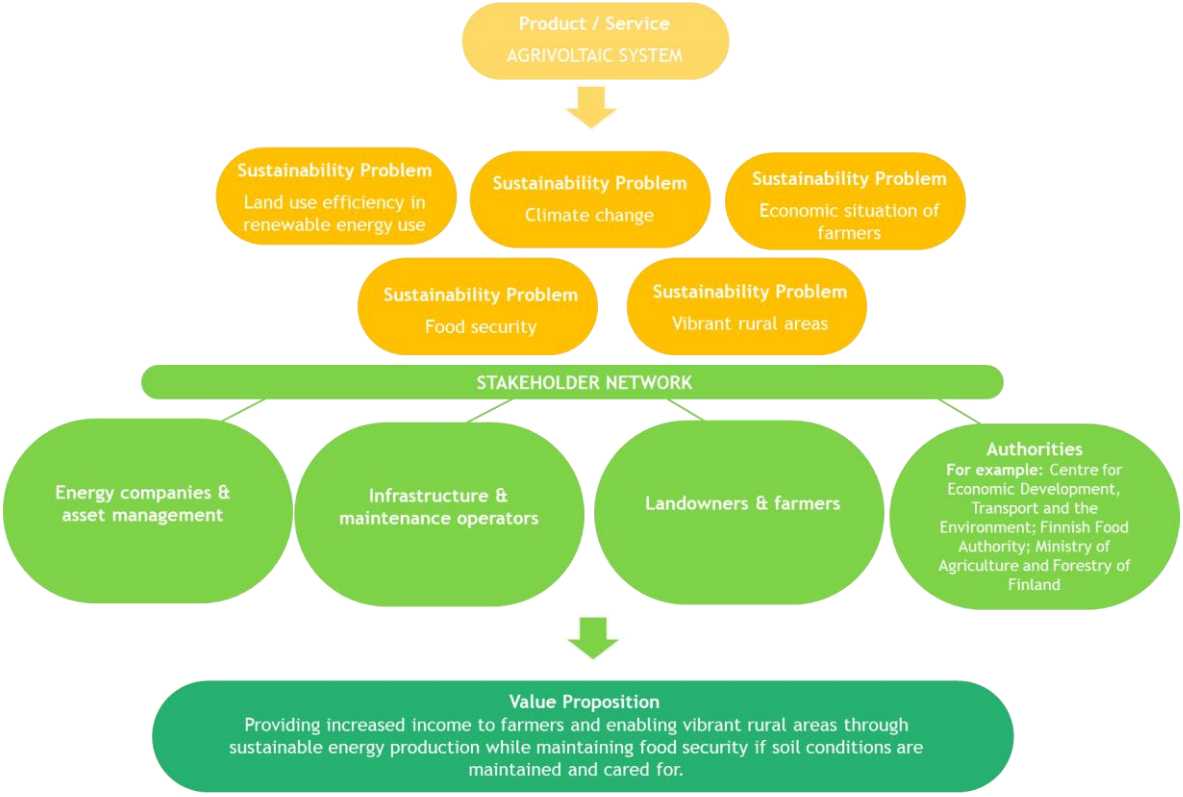

Figure 25: Sustainable value proposition of agrivoltaic systems

The product and service in this case would be agrivoltaics, which would tackle sustainability problems such land use efficiency, since due to the dual use of the land, it would be possible to provide both food as well as clean energy in the same land area, which then in turn supports climate change mitigation and promotes food security, when the land is not for example completely allocated for energy production. These aspects can be considered under environmental sustainability when considering the three pillars of sustainability as reviewed in chapter 2.4.1. The agrivoltaic system can also provide additional income for farmers through land rental income, which then promotes the economical sustainability of farmers and in turn could ensure longevity in the farming communities, when the farming operations would not be solely dependent on the crop market prices as well as mitigate the risks that for example climate change and challenging weather conditions provide. This alignes with the Common agriculture Policy which is reviewed in chapter 2.3.2. In the questionnaire the possibility to increase income was highlighted as an important factor in relation to agrivoltaic systems. With more financial stability farmers can increase the resilience of their operations, which in turn also effect positively on the food security but also can help maintain vibrant rural areas, which is linked to social sustainability aspect and is also highlighted in the Common Agricultural Policy. While agrivoltaic systems can be seen as solving multiple sustainability problems, it in turn also brings up questions related to for example the soil conditions and soil conservation, landscape changes of rural areas and effects on biodiversity, which also would need to be examined and addressed.

Different stakeholders in the business development framework would include the farmers and landowners, energy providers and asset management, infrastructure, and maintenance operators as well as authorities. In addition to this, the stakeholder network could be expanded to include for example neighbors of the land area where the agrivoltaics system would be built, since in cases of traditional photovoltaics system, the local community is included also in the environmental assessment procedures, but in this case the focus of the model in more on the business development early stages, so for simplicity the neighbors are excluded from this. The information farmers have regarding the farming operations in general and for example soil conditions can be considered crucial in regard to agrivoltaics system development, since the placement of panels, the microclimates the panel create, shading, suitable crop selection as well as subsidy applicability are just a few of the factors that affect the farming operations, and which need to be considered when installing the agrivoltaic system. For example in the questionnaire, a concern regarding the operation and maintenance during growing season was raised, and this would then be something that should be gone through and planned out thoroughly with farmers together with the energy producers, infrastructure provider and maintenance operators in order to ensure a reliable energy production in such way that for example possible maintenance needs for the panels and installations would not have adverse effects on the crops and farming operation. One major stakeholder group is also different authorities, since subsidy applicability was also raised as a concern in the questionnaire so the development of argivoltaic systems should be done together also with various authorities in order to ensure for example legislative aspects. For example, as mentioned in chapter 2.1.2, currently if the land that is allocated to solar panels, this area does not qualify for farming subsidies. Most likely these types of regulations would need to be reviewed if agrivoltaics systems would be something that farmers would want to proactively adopt as part of their business operations, in order to make sure the regulations would support the operation in the most sensible way.

As discussed in chapter 2.4.2, a business model consists of three elements, which include value proposition, value creation and delivery system and value capture. The value proposition for agrivoltaic systems could be the following: *Providing increased income to farmers and enabling vibrant rural areas through sustainable energy production while maintaining food security if soil conditions are maintained and cared for*. Soil conditions and land restoration after the rental period were highlighted in the answers of the questionnaire. More research would be needed on the long-term effects of panel infrastructure on soil conditions in order to determine if agrivoltaics systems would overall be a good solution when taking into consideration all the benefits and disadvantages. In the value proposition it is good to highlight that maintaining the soil conditions is a crucial key element enabling or disabling the feasibility of the agrivoltaic system as a favorable option for landowners. Due to this soil conditions and restoration can be considered as one of the key elements to be considered in the agrivoltaics business development and should then be thoroughly examined and discussed between different stakeholders and solutions, guidelines and procedures should be provided in order to ensure that the conditions will remain as they are – or if possible, improve – throughout the rental period. (Figure 26)

Figure 26: Key topics of agrivoltaics business development

Other key elements include profitability of operations, crop selection and operational practices. (Figure 26) Based on the questionnaire one of the main positive aspects of the agrivoltaic system from landowners’ perspective is the additional income. The agrivoltaics business development should of course be financially beneficial for all stakeholders, and in order to determine what are the conditions where this would apply, co-operation especially between the energy producers and asset management is needed with the local authorities and landowners.

Crop selection did not come up in the answers of the questionnaire as such, but concerns regarding the use of large machinery within panel constructions and possible issues during the growing season were brought up, and these are linked with crop selection, since it determines what kind of farming practices are required in the area. The panels can also affect the growing conditions of the crop through shading and moisture as discussed in chapter 2.1.2. Finding a suitable selection of crops that are able to grow and thrive within panel constructions when considering the used machinery and different required farming operations, such as sowing and harvesting and soil conditioning as well as crops that are not negatively affected by the panel constructions itself can be seen as a necessity when further developing agrivoltaics business models.

Operational practices in general need to be considered from the perspective of all stakeholders and throughout the lifecycle of the agrivoltaic system and these need to be examined to see how they would fit together with the farming practices. As already discussed earlier, possible maintenance needs during the growing season was brought up in the questionnaire, and also topics such as permit matters, who will “take care of the mess when the panels fall apart”, possible deterioration of drainage pipes, bureaucracy and eligibility to farming subsidies were raised as concerns (Table 2) and well-functioning co-operation and understanding towards farming as a business were valued mostly important or very important (Figure 24).

Transparency regarding contract terms and in general as well as a good flow of information was considered important, as well as trustworthiness and reliability of the parties involved was valued (Table 4). Because there are variety of stakeholders and agrivoltaics would overlap with the existing business operations of farms, in the development of agrivoltaics business model it would need to be very clearly mapped out what are the best practices and goals in relation to farming, agrivoltaics system construction, operation, maintenance, disassembly and general asset management of the power plant during its lifecycle as well as the requirements of the different authorities and then in close co-operation find commonly agreed practices on running the operation in such a way, that it benefits both the farmer and system operator throughout the lifecycle in a way that complies with the rules and regulations of the different authorities that would be involved. Also, the different authorities might need to review their conditions and guidelines to see if they support such business development in the most suitable way without of course compromising environmental safety.

5 Conclusions and suggestions for further study

Agrivoltaics systems are already common to certain extent in other parts of the world such as Germany and the United States. In Finland these systems are not yet that common and majority of farmers and landowners might not be that familiar with the term. There, however, could be interest in such systems from the farmers and landowners' perspective if certain conditions are met, such as maintaining the soil conditions and restoration of the land after the rental period as well as suitable compensation. Development of these systems also depend on various stakeholders as well as the development of the energy transition and required infrastructure as well as market needs, and not the least on farms and their operation practices.

The preliminary innovation model presented in chapter 4.5 visualized the sustainable value proposition of agrivoltaic system, provided insight to different sustainability problems that agrivoltaics could tackle and clarified the stakeholder network. The value proposition itself suggests that through the agrivoltaics systems farmers and landowners can gain increased income which in turn increases the resilience of the farming operations and through this can support maintain and developing more vibrant rural areas which is also one of the Common Agricultural Policy goals. In addition to this, the value propositions included the production of renewable and sustainable energy while maintaining food security, which helps tackle climate change. The value proposition also highlights the critical aspect of keeping the soil conditions viable for agriculture in the long term, and this can be seen as a key condition for proceeding with the agrivoltaics business development as well as the overall sustainability of the solution in general.

Agrivoltaic systems can provide a vast field of further study opportunities, for example starting from the already often mentioned effects on soil conditions, but also the effects on for example biodiversity in general and when compared to traditional photovoltaic systems. Suitable crop varieties have been studied to a certain extent but more studies on this in the Nordic climate and sunlight conditions would also be beneficial for the further development of the agrivoltaics systems and business models.

Also, various technical aspects provide subjects for further studies, such as would it be possible to create modular panel constructions that farmers and system operators could easily relocate to a similarly suitable area if the farming operations would require changes in the currently allocated land area. From economical point of view research could be made in order to find out the most cost-effective solution and is such systems financially profitable from the perspective of the system provider and energy producer, when considering the conditions and restrictions that landowners might want to set for the systems in order for them to be willing to integrate those systems to their operation. It would also be interesting to know what role farmers and their agrivoltaics systems could play in the overall energy system in the future, when also considering energy storage systems and flexibility needs of the energy markets.

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Figures

Tables

Appendices

Appendix 1: Agrivoltaics questionnaire

Agrivoltaics - Kyselytutkimus maatalousaurinkosähköhankkeista

Oheisella kyselyllä on tarkoitus selvittää maanomistajien mielipiteitä ja näkemyksiä Agri-PV / agrivoltaics eli maatalousaurinkosähköhankkeisiin liittyen. Maatalousaurinkosähköhankkeissa peltomaata käytetään samanaikaisesti sekä aurinkosähkön tuottamiseen sekä viljelyyn ja/tai laiduntamiseen. Kyselytutkimus on osa Laurean ammattikorkeakoulussa tehtävää YAMK-opinnäytetyötä, jossa käsitellään maatalousaurinkosähköhankkeiden kehittämistä ja kyselyn tuloksia hyödynnetään opinnäytetyössä. Kysymyksissä ei kerätä henkilötietoja ja kyselyn vastaukset säilytetään vain tutkimuksen ajan. Vastaamisessa kestää n. 10-15 minuuttia ja kysely sulkeutuu 31.3.2024 mennessä.

Kiitos, jos maltat vastata ja auttaa opinnäytetyön edistämisessä!

Mikäli kyselyyn tai opinnäytetyön aiheeseen liittyen herää kysymyksiä, olethan yhteydessä:
maria.seppala@student.laurea.fi

Lisätietoa agrivoltaics/maataloussähköteknologiasta on katsottavissa täällä: https://www.youtube.com/watch?v=QKRq87EKUZc

Osa 1 ...

1. Missä käytössä tällä hetkellä omistamasi pellot ovat?

- [ ] Viljelen itse / laidunkäytössä omassa tuotannossa
- [ ] Ulkopuoliselle vuokrattuna
- [ ] Muu

2. Missä päin Suomea pellot sijaitsevat?

- [ ] Ahvenanmaalla
- [ ] Etelä-Karjalassa
- [ ] Etelä-Pohjanmaalla
- [ ] Etelä-Savossa
- [ ] Kainuussa
- [ ] Kanta-Hämeessä
- [ ] Keski-Pohjanmaalla

- ☐ Keski-Suomessa
- ☐ Kymenlaaksossa
- ☐ Lapissa
- ☐ Pirkanmaalla
- ☐ Pohjanmaalla
- ☐ Pohjois-Karjalassa
- ☐ Pohjois-Pohjanmaalla
- ☐ Pohjois-Savossa
- ☐ Päijät-Hämeessä
- ☐ Satakunnassa
- ☐ Uudellamaalla
- ☐ Varsinais-Suomessa

3. Viljeletkö osana maatalousyhtymää/osakeyhtiötä tai vastaavaa yhtiömuotoa vai itsenäisesti?

- ◯ Maatalousyhtymä tai vastaava yhtiömuoto (esim. osakeyhtiö)
- ◯ Viljelen itsenäisesti
- ◯ En viljele itse, maat ovat vuokrattu
- ◯ Muu

4. Mikäli vuokraat peltomaita, milloin viimeksi niitä on viljelty omassa suvussasi?

- ◯ Pellot eivät ole vuokralla
- ◯ 0-5 vuotta sitten
- ◯ 6-10 vuotta sitten
- ◯ Yli 10 vuotta sitten
- ◯ Maat eivät ole ikinä olleet omassa suvussani viljely/laidunkäytössä

5. Mikäli peltomaat ovat tällä hetkellä itsellä viljelyksessä/laidunkäytössä, onko teillä tilalle jatkaja tiedossa?

- ◯ En viljele itse, maat ovat vuokrattu
- ◯ Kyllä
- ◯ Ei

6. Mikäli pellot ovat omassa käytössä eikä vuokrattuna, teetkö maanviljelyn lisäksi muita töitä esim. koneurakointia, majoituspalveluita tai oletko tilan ulkopuolella palkkatöissä?

- ☐ Koneurakointi
- ☐ Majoituspalveut
- ☐ Muualla tilan ulkopuolella palkkatöissä
- ☐ Muu

7. Mihin ikäryhmään kuulut?

- ◯ alle 30 vuotias
- ◯ 31-40 vuotias
- ◯ 41-50 vuotias
- ◯ 51-60 vuotias
- ◯ Yli 61 vuotias

8. Ovatko termit "agrivoltaics", "agri-PV" tai "maatalousaurinkosähkö" tuttuja entuudestaan?

- ◯ Kyllä
- ◯ Ei

9. Ovatko energiayhtiöt lähestyneet teitä aurinko- tai tuulivoiman maanhankintaan liittyen aikaisemmin?

○ Kyllä

○ Ei

10. Olisitteko kiinnostuneita vuokraamaan maitanne aurinkovoiman rakentamiseen?

○ Kyllä

○ En

11. Olisitteko kiinnostuneet vuokraamaan maitanne aurinkovoiman käyttöön, mikäli maita voisi tietyin rajoittein hyödyntää samanaikaisesti edelleen myös maanviljelytoiminnassa?

○ Kyllä

○ En

12. Mitkä tekijät kokisit tärkeiksi, mikäli maita käytettäisiin samanaikaisesti aurinkoenergiantuotantoon sekä viljelyyn? Huomaa, että kysymysikkuna jää osittain piiloon, joten osa vastausvaihtoehdoista tulee näkyviin alapalkkia vierittämällä.

	Ei lainkaan tärkeää	Jokseenkin tärkeää	En osaa sanoa	Tärkeää	Erittäin tärkeää
Paneelien muunneltavuus / asennusten joustavuus mahdollisten tuotantosuunnan muutosten mahdollistamiseksi vuokrausjakson aikana	○	○	○	○	○
Maan vuokrauksesta saatava korvaus/lisätulo viljelytoiminnan yhteydessä	○	○	○	○	○
Säännölliset palautekeskustelut energiantuottajatahon kanssa	○	○	○	○	○
Tieto tuotetusta energiasta	○	○	○	○	○
Maaperän viljelykunnon säilyminen ennallaan tai parantuminen vuokrausjakson aikana	○	○	○	○	○
Maaperän ennallistaminen vuokrausjakson päätteeksi	○	○	○	○	○

13. Minkä kokisitte haastavaksi/mikä aiheuttaisi teille huolta, mikäli maita käytettäisiin samanaikaisesti viljelyyn sekä aurinkoenergiantuotantoon?

Kirjoita vastaus

14. Miten kokisitte, että lähiympäristössä suhtauduttaisiin agrivoltaics/maatalousaurinkosähköhankkeeseen verrattuna perinteiseen aurinkovoimahankkeeseen (missä koko peltoala olisi aurinkovoimalakäytössä eikä viljely olisi mahdollista) mikäli maillenne tulisi agrivoltaics hanke?

Kirjoita vastaus

15. Mikäli olisi mielestäsi sopiva vuokra-aika agrivoltaics/maatalousaurinkosähköhankkeelle, jolloin maat olisivat yhteiskäytössä viljelyn ja energiatuotannon kanssa?

- ◯ Alle 10 vuotta
- ◯ 11-20 vuotta
- ◯ 21-30 vuotta
- ◯ 31-40 vuotta
- ◯ Yli 41 vuotta

16. Mikäli vuokraisitte maitanne osittain agrivoltaics/maatalousaurinkosähköhankkeeseen, mitkä tekijät olisivat teille tärkeitä yhteistyökumppania ajatellen? Huomaa, että kysymysikkuna jää osittain piiloon, joten osa vastausvaihtoehdoista tulee näkyviin alapalkkia vierittämällä.

	Ei lainkaan tärkeää	Jokseenkin tärkeää	En osaa sanoa	Tärkeää	Erittäin tärkeää
Tunnettu toimija markkinoilla	◯	◯	◯	◯	◯
Yhteistyön toimivuus	◯	◯	◯	◯	◯
Aktiivinen kommunikointi koko vuokrausjakson ajan	◯	◯	◯	◯	◯
Säännöllisten vuokratulojen mahdollistaminen	◯	◯	◯	◯	◯
Ymmärrys maanviljelyliiketoimintaa kohtaan	◯	◯	◯	◯	◯
Toiminnan joustavuus/mukautuvuus maanviljelyn ehdoilla	◯	◯	◯	◯	◯
Mahdollisuus päästä mukaan kehittämään toimintaa / viljelyn ja energiantuotannon yhdistämistä	◯	◯	◯	◯	◯

17. Onko edelliseen kysymykseen liittyen muita asioita, mitä kokisit tärkeäksi yhteistyöhön ja yhteistyökumppanin valintaan liittyen, mitä edellisissä vaihtoehdoissa ei ollut mainittu?

Kirjoita vastaus

18. Mistä asioista haluaisit erityisesti lisätietoa oman päätöksenteon tueksi, mikäli harkitsisitte maiden vuokraamista aurinkoenergiatuontantoon siten, että maita käytettäisiin samanaikaisesti myös viljelyyn/laiduntamiseen?

Kirjoita vastaus