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Biochar for Carbon Neutral Farming: A Case Study of Greenhouse Horticulture in Norway

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ABSTRACT

Norway is on the list over nations who directly contribute to a significant part of the European and global greenhouse gas-emissions and is a direct contributor to global warming and its related problems. As a result of this the nation is aiming to transition away from being a fossil fuel-based economy and is working towards becoming a low-emissions society by 2050.

Biochar is one of the measures predicted to have the highest potential of reducing the carbon-emissions from the Norwegian agricultural sector, and there are indications that it can play an important role in dealing with the threats of climate change and achieving agroecosystem sustainability.

The technical, organisational and economical side of biochar implementation is already being researched, but it is important to investigate relevant social, cultural, and political factors for implementing biochar in Norway as well. Farmers may play a key role in this. As the horticultural greenhouse industry has received criticism for being heavily dependent on fossil inputs such as natural gas, peat and CO2-gas, this might be a niche for pioneering a wider adoption of renewable biochar pyrolysis technology.

A case that is currently under particular pressure when it comes to sustainability and transition is the horticultural industry of Finnøy and Rennesøy municipalities in the west of Norway. One of the national goals is namely to phase out all use of fossil energy in the greenhouse industry, and Rogaland County (where Finnøy and Rennesøy are located) aims to make their greenhouse production carbon neutral.

This has been the focus of my thesis research, and through in-depth interviews with three horticultural greenhouse farmers I have investigated some prerequisites, limitations and enabling factors for such an implementation. I have also looked at the attitude towards biochar in the region through talking with relevant stakeholders.

One of these stakeholders, Sandnes Municipality is the first stakeholder to make use of biochar pyrolysis technology in the west of Norway, and they have demonstrated that biochar has the potential to replace several fossil-based inputs in the Stavanger Region.

My findings show, however, that some prerequisites need to be fulfilled in terms of ensuring a low risk, predictable, pleasant and stable working-place for the farmers, before this is a viable solution for horticulture in Finnøy and Rennesøy. I have looked at the enabling and limiting factors for fulfilling these prerequisites.

Developing the ideas and implementation of biochar in Norwegian greenhouse horticulture further could contribute to reaching the goals of a carbon-neutral horticultural industry. This would in turn reduce the environmental footprint of the Norwegian agriculture, and help Norway comply with its commitments in the Paris Agreement. Yet some practical questions still remain unanswered. Given the positive responses from the farmers there seems to be a foundation already for testing this technology, and answering some of these questions, in horticulture in this region relatively soon.

SAMMENDRAG (ABSTRACT IN NORWEGIAN)

Norge befinner seg på listen over nasjoner som direkte bidrar til en betydelig del av de europeiske utslippene av drivhusgasser, og er derfor en direkte bidragsyter til global oppvarming og problemene det medfølger. Som et resultat av dette er det et nasjonalt fokus på å gå vekk fra en fossil-basert økonomi, og jobber mot å bli et lavutslippssamfunn innen 2050.

Biokull er en av metodene som spås å ha det høyeste potensialet for å redusere karbon-utslippene fra norsk landbrukssektor, og det finnes indikasjoner på at biokull kan spille en viktig rolle i å håndtere truslene fra klimaendringer og det å oppnå agroøkosystemisk bærekraft.

De tekniske, organisatoriske og økonomiske sidene av biokullimplementering forskes det allerede på, men det er også viktig å undersøke relevante sosiale, kulturelle og politiske faktorer for å implementere biokull i Norge. Bønder kan spille en viktig rolle her. Ettersom veksthusindustrien har fått kritikk for å være svært avhengig av fossile innsatsmidler så som naturgass, torv og CO2-gass, kan dette være en nisje som kan rydde veien for en bredere implementering av fornybar biokull-pyrolyse-teknologi.

En case som for tiden er under stort press når det kommer til bærekraft og overgang, er veksthusindustrien in Finnøy og Rennesøy kommuner på vestkysten av Norge. Ett av de nasjonale målene er nemlig å fase ut all bruk av fossil energi i veksthusindustrien, og Rogaland Fylke (hvor Finnøy og Rennesøy befinner seg) søker å gjøre veksthusindustrien karbonnøytral.

Dette har vært fokuset for denne masteroppgaven. Gjennom dybdeintervjuer med tre veksthusbønder har jeg undersøkt noen forutsetninger, begrensinger og tilretteleggende faktorer for en slik implementering. Jeg har også sett på holdninger til biokull i regionen gjennom samtaler med relevante interessenter.

En av disse interessentene, Sandnes Kommune, er de første til å ta i bruk biokull-pyrolyseteknologier i Vest-Norge, og de har demonstrert at biokull har potensiale til å erstatte flere fossil-baserte innsatsmidler i Stavanger-Regionen.

Mine funn viser forøvrig, at det er flere forutsetninger som må være tilstede for å sørge for et lav-risiko, forutsigbart, trivelig og stabilt arbeidsmiljø for bøndene før dette kan være en mulig løsning for veksthusindustrien in Finnøy og Rennesøy. Jeg har sett på de tilretteleggende og begrensende faktorene for at disse forutsetningene skal kunne være tilstede.

Det å utvikle ideene og implementeringen av biokull i Norsk veksthusindustri videre kan bidra til å nå målene om en karbon-nøytral vektshusindustri. Dette vil i sin tur redusere miljøbelastningen fra norsk landbruk, og hjelpe Norge med å nå sine forpliktelser i Paris-avtalen. Likevel står flere praktiske spørsmål fremdeles ubesvarte. Basert på de positive tilbakemeldingene fra bøndene ser det ut til at det er et grunnlag for å teste denne teknologien i veksthusindustrien i denne regionen i nær fremtid.

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ABBREVIATIONS

GHG – Greenhouse Gas
NGF – Norwegian Gardeners Federation (Norsk Gartnerforbund)
IVAR IKS – Interkommunalt Vann-, Avløp- og Renovasjonsselskap
NIBIO – Norwegian Institute for Bio Economy
CCS – Carbon Capture and Storage
BioCCS – Bio-Carbon Capture and Storage
DPOR -- Data Protection Official for Research
NGF – Norsk Gartnerforbund [Norwegian Gardeners Federation]

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1 INTRODUCTION

The strain on our global environment is increasing. In 2017 the global energy-related[1] CO2 emissions were the highest ever measured (International Energy Agency, 2018). These emissions increased in 2018 and are predicted to increase further in 2019 (Le Quéré et al., 2018). This is alarming because energy production and energy use counts for over 80 % of total Greenhouse Gas (GHG) Emissions in Europe (European Environment Agency, -).

Norway is the largest oil-exporting economy in Europe, and the third-largest exporter of natural gas in the world (Norsk Petroleum, 2019). Extraction of oil and gas is the largest singular source of GHG-emissions in this country (Statistics Norway, 2018a). Norway is consequently put on the list over nations who directly contribute to a significant part of the European and global GHG-emissions. Norway is thus also a direct contributor to global warming and its related problems.

The International Energy Agency, of which Norway is a member, state that:

> "...as the world looks to cut its reliance on fossil fuels, Norway's government should also consider measures to prepare for a future with lower oil and gas revenues." (International Energy Agency, -)

In thread with this statement, Norway is aiming to transition away from being a fossil fuel based economy, and is working towards becoming a low-emissions society by 2050, following the Paris Agreement of 12th of December 2015. This is established in the Norwegian Law on Climate Goals (Klima- og miljødepartementet, 2017) that came into force 1st of January 2018. The law states that:

> "The goal is that the GHG-emissions in 2030 are reduced by at least 40 percent, [and that they] by 2050 are reduced [by] 80 to 95 percent from the level measured in 1990 (reference year)."

These are ambitious goals, and there are several ways of reaching them. One way is carbon capture and storage (CCS) which is one of the stated top priorities of the current Norwegian government (Olje- og energidepartementet, 2018). The, until now, biggest and most expensive CCS-project in Norway is the failed Mongstad Project for CO2-cleansing (Hykkerud, 2018).

With Mongstad being a disappointment, it is natural to look at cheaper and more achievable ways of carbon sequestration. These methods are called BioCCS (Aarø, 2018). Biochar is an example of a promising BioCCs alternative.

Biochar is charcoal made from organic matter, under high heat, in a low-oxygen environment (pyrolysis). It has a high inner surface due to its many pores, and decomposes very slowly -- predictions range from a few hundred years (Wang et al., 2016) up to several

[1] Energy-related emissions are emissions from the energy sector. The energy sector mainly includes companies involved in the exploration and development of oil or gas reserves, oil and gas drilling and refining, or integrated power utility companies including renewable energy and coal (Chen, 2017).

thousand years (Kuzyakov et al., 2014). Biochar is a so-called eco-innovation and can thus be compared to other similar eco-innovations such as biogas.

What separates biochar from most other eco-innovations is that it seems to be a package solution providing a way to manage waste, to produce sustainable (and valuable) growth and fertilization media, to produce heat and energy, and to store carbon long-term.

As an example, the Norwegian Government estimated that in 2020 biochar made from straw and later stored in the soil could reduce the Norwegian emissions with 560 000 Mg CO2-equivalents (Klima- og forurensningsdirektoratet, 2010). In comparison, in 2017 the GHG-emissions from the Norwegian agricultural sector represented 4.45 million Mg CO2-equivalents (Miljødirektoratet, 2018).[2]

Biochar is thus one of the measures predicted to have the highest potential of reducing the carbon-emissions from the Norwegian agricultural sector (Klima- og forurensningsdirektoratet, 2010), and there are indications that biochar can play an important role in dealing with the threats of climate challenges and agroecosystem sustainability (Nair et al., 2017). However, further research still remains to be conducted before we have the knowledge that can enable us to make informed decisions on whether it is safe to apply biochar technologies to the Norwegian agricultural system at a large scale.

To mend this knowledge gap, several feasibility and pilot projects have been set in motion. As an example, Tellnes et al. (2017) mentioned biochar as a promising alternative to peat – which is commonly used as a growth medium in horticulture. They conclude that more research is needed to be able say this for sure.

NIBIO (Norwegian Institute for Bio Economy) are, through their Carbo Fertil Project, working on developing pyrolysis innovations and biochar fertilizer products, as well as looking at the economic merit of biochar in the agricultural sector, climate change mitigation benefits for Norway, and a carbon reporting systems for Norway's commitments to the Paris agreement (NIBIO, 2018).Their research will be concluded in 2021.

With the technical, organisational and economical side of biochar already being researched, Thomassen et al. (2017) stated the importance of investigating relevant social, cultural, and political factors for implementing biochar in Norway as well. They highlighted farmers and their potential to play a key role in producing and using biochar on the small, medium, and large scale. Otte and Vik (2017) is currently the only Norwegian report that has looked at the farmers perspective on biochar in Norway. They also emphasize the need for more research on the topic:

> "[T]he situation is complex, and the implementation of biochar systems requires a thorough analysis of relevant social and organizational factors that not only address the physical technology and economic benefits."
> (Otte & Vik, 2017)

[2] The GHG-emissions from the Norwegian territory represented 52,7 million Mg CO2-equivalents in 2017 (Statistics Norway, 2018b).

Based on this need for more research on the social perspective on biochar in Norway, my first research question is:

> What role do innovations such as pyrolysis play in developing sustainable and resilient rural communities when transitioning from fossil based economies?

To be able to answer this question, I have identified a case that is currently under particular pressure when it comes to sustainability and transition, namely the horticultural industry of Finnøy and Rennesøy municipalities in the west of Norway. One of their main industries is tomato production in greenhouses (horticulture), and they produce more than 30% of the Norwegian tomatoes (Skartveit, 2018). Rogaland County, where Finnøy and Rennesøy are located, produces about 92% of the Norwegian tomatoes (Knutsen et al., 2019).

This production has, in the light of the Norwegian climate goals, received criticism for being heavily dependent on fossil inputs such as natural gas, peat and CO2-gas. One of the national goals is to phase out all use of fossil energy in the greenhouse industry by 2020, and Rogaland County aims to make their greenhouse production carbon neutral by 2030 (Rogaland Fylkeskommune, 2011). The largest challenge to achieve that will likely be to convince the horticultural industry to switch to renewable energy sources (ibid.), because there are currently few affordable and sustainable alternatives for these farmers to use instead.

The increased restrictions and demands when it comes to sustainability are thus putting the tomato industry in Rogaland at risk. The upcoming merge between Finnøy, Rennesøy and Stavanger Municipality in 2020 puts even more pressure on the farmers (Næringsforeningen, 2019).

Based on this need for a more research on the social science perspective on biochar in Norway, my second research question is:

> What are current economic, socio-technical and agroecological possibilities and limitations for adopting biochar technologies in greenhouse horticulture in Finnøy and Rennesøy?

I will in addition to this also briefly discuss *potential biochar solutions for this region* in transition.

The methods I have chosen for answering these questions are qualitative, explorative interviews with farmers and stakeholders relevant to the case of biochar, horticulture, and Finnøy and Rennesøy Municipalities.

2 METHODS AND MATERIAL

My strategy was to obtain data to be able to answer the research questions through a **case study** at farm and regional levels. I have used an inductive “bottom-up” approach, as described by Alexandritis (2006) referenced by Dudovskiy. That approach includes looking at multiple spatial and temporal scales with a focus on understanding the dynamics, robustness, and resilience of the case.

I have used several **assumptions** as a starting point of my work (see page 11).

To gather data about the case I used a combination of **informing and inviting** (through meetings and invitations), **network-building** (“snowballing” through conversations and interviews with stakeholders) and **gathering information** (in-depth interviews with farmers).

2.1 THE CASE

I chose the bottom-up approach, starting with a very specific case, because the farmers’ perspectives should be included in the evaluation of biochar as a tool. This is especially important when evaluating the implementation of farm-scale pyrolysis-systems versus industrial-scale pyrolysis systems.

There is already research being conducted with a natural science perspective on biochar in Norway, especially lead by NIBIO, whereas the sociological side is being given less attention. I therefore wanted to take a more sociological inductive approach through interviewing farmers.

The location of the case, Finnøy and Rennesøy (see Appendix 1), are examples of **rural societies in transition**, especially due to the merge with “New Stavanger Municipality” in 2020. After the merge the New Stavanger will be the capital for energy in Norway, as well as one of the most important municipalities for agriculture, aquaculture and tourism (Nye Stavanger kommune, -).The horticultural industry will be a large part of this image as well, especially tomato production.

Even if the situation in the Stavanger Region is quite unique, the challenges of reducing the carbon footprint are not. Thus, I decided to focus my research on the horticulturalists of Finnøy and Rennesøy, with the aim that the results from this case may offer knowledge more globally applicable.

2.2 ASSUMPTIONS

I had several assumptions when starting my case-study. These were the starting point of my research:

- Biochar could be a tool for the horticultural industry to:
    - manage waste, surplus and residue products.
    - produce heat and electricity for use on the farms
    - produce CO_2 for use as fertilization in the greenhouses
    - produce their own growth medium and soil improvement
    - increase the sustainability of the industry

- Biochar could be a part of creating jobs and increasing the sustainability and resiliency in the New Stavanger Municipality.
- The adoption of biochar in the region depends largely on the farmers and their interest in the topic, as well as their willingness and capacity to change their production to include biochar.
- It will be beneficial for the farmers and other possible biochar stakeholders if a network or organization for biochar was established in the region.

2.3 Informing and inviting

The research project was done in collaboration with IVAR IKS, as a part of my internship with them. My mentor there, Mr. Rudolf Meissner, has been my main contact and door opener for reaching most of the other stakeholders. Starting with actors already known to IVAR IKS and myself I was subsequently pointed in the direction of other interesting stakeholders – a so called '**snowball sampling**'(Dudovskiy, - -b).

Once the stakeholders (see Network-building page 12) were identified, I invited each of them to meet me for a conversation about biochar and how it could relate to their field. These invitations were sent per e-mail and post.

To ensure the privacy of the stakeholders, I only reached out per e-mail to those where an e-mail address was listed on their own, public website. Most of the farmers did not have such a website, and thus I decided to send the invitations to them per post.

The invitations sent to the farmers were based on a template for consent provided by **the Data Protection Official for Research** (DPOR) (see the invitation letter describing my research project in appendix 3). My project was also approved and registered with the DPOR under project number: 60869.

Because of **privacy demands** from the Norwegian Government[3], I could only use contact information available for free use, and given voluntarily (meaning I could not ask the municipalities or private persons to give me the contact information of the farmers). I used the web pages of the Norwegian Brønnøysund Register to search their sub-register Enhetsregisteret (a public register for organisations).

I used different search words in Norwegian related to horticulture and found that most tomato growers were registered under the code "**01.130 Dyrking av grønnsaker, meloner, rot- og knollvekster**" (cultivation of vegetables, melons, root and spud plants). I thus limited my search to that code and used this code together with the search words "Finnøy" and "Rennesøy" to locate most of the tomato farmers registered in the two municipalities.

From this search, I got a list of about **60 farmers**. Finnøy Municipality informed me that **only about 30 of them were still active**, but there was no information in the register or with the municipality on which of the 60 farms that were still in operation. To be sure that I reached most of them, I therefore sent invitations by post to all 60 on the list.

[3] New and stricter rules for data protection were put in place in during July 2018 (Datatilsynet, 2018).

It was also important to make sure that the participants had a basic understanding of the topic in the light of municipal changes, climate adaptations and agricultural challenges before I conducted the interviews. To ensure this I sent all stakeholders a **leaflet,** which I had made, with information about biochar and how it could relate to the horticultural industry (appendix 5).

These two documents were sent per post to the farmers together with an **invitation letter**, (see template for this in appendix 3). The number of responses in different categories are described in table 1 below.

Table 1: Number of responses received from horticultural gardeners in Rennesøy and Finnøy on invitations sent by post.

Invitations sent by post	60
Invitations returned to unopened to sender	3
Replies received	9
Replies indicating that they were no longer active	1
Replies indicating that they were not interested in participating	1
Replies indicating that they wanted to participate	5
Farmers who withdrew from participation	2
Farmers interviewed	3

It is possible that some of the currently active farmers did not receive an invitation. However, upon invitation from Finnøy Municipality I also presented my work on two seminars held for the tomato producers in Finnøy and Rennesøy. The main purpose of these presentations was to invite farmers to participate in my study.

I made a list available on the seminars that the farmers could write their name and contact information on, and I also made the leaflet available for them to take home. The leaflet had my contact information on it. No farmers wrote their name on the list, nor contacted me after the meetings. There was thus not much more that I could do within my means and time limit to recruit more farmers.

2.4 NETWORK-BUILDING AND SNOWBALLING

Most of the stakeholders either work with biochar or had no prior knowledge of biochar before my conversation with them (see table 2).

Table 2: Stakeholders and their knowledge of biochar prior to their conversation with me.

Work with Biochar	Have Heard of Biochar	Not Familiar with Biochar
IVAR IKS	NGF	Finnøy Municipality
Sandnes Municipality	Klimapartnere Rogaland	Rennesøy Municipality
Stavanger Municipality		Ryfylke Næringshage
NIBIO		The farmers
BioMaCon		

The conversations and seminars I had with these stakeholders are listed below:

2.4.1 NIBIO (Norwegian Institute for Bioeconomy)

- Arne Sæbø - NIBIO Særheim. Interviewed in person 18th of September 2018 in Nibio Særheim, Klepp Municipality. Interviewed about their research on biochar and his views on the future of biochar in Norway and in horticulture.
- Adam O'Toole - NIBIO Ås, e-mail contact and conversations during a IBI study tour to Austria, June 2018. Conversation on their research on biochar and future visions for biochar in Norway.

2.4.2 Rogaland County and Municipal Representatives

- **Sandnes Municipality** represented by Jan Egil Gjerseth and Arne Jørgensen. Meeting in person 12th of June 2018 in Sandnes. Presented my thesis for them, and they gave me information on their new pyrolysis facility.
- **Finnøy Municipality** represented by Silke Ullrich and Marit Magdalene Schweiker. Meeting in person 2nd of July 2018 in Finnøy. Presented my work and learned about the status of horticulture in Finnøy.
- **Klimapartnere Rogaland** represented by Christian Herheim. Meeting in person 8th of August 2018 in Stavanger. Presented my thesis and learned about the work of Klimapartnere [Climate Partners] as well as the then upcoming work-meeting on sustainability in horticulture.

2.4.3 Other Organizations

- **Ryfylke Næringshage,** represented by Tove Sivertsen. Meeting in Person 10th of July 2018 in Finnøy. Presented my work and learned about Ryfylke Næringshage and their work with farmers, and about the yearly Tomato Festival in Finnøy.
- **Norges Gartnerforbund [Norwegian Gardeners Federation], r**epresented by Martin Knoop. Meeting in person 26th of July in Stavanger. Discussed my thesis

work and learned about the status of energy needs and uses in horticulture in Norway.

- **BioMaCon**, represented by Ulrich Suer. Communication via e-mail regarding the pyrolysis units they make, one of which has been sold to Sandnes Municipality. He also presented his business on the Biochar Seminar in Sandnes Municipality.

2.4.4 Seminars

- **The Tomato Day** 17th of August 2018, Finnøy Municipality. Professional meeting for horticulturalists, politicians and other organizations on making tomato production more sustainable. I presented my work and invited horticulturalists and others to sign up on the interest list. Only Nibio Særheim wrote themselves on the list, but I was already in contact with them.

- **Working meeting for Sustainability in Horticulture**, 29th of August 2018, Finnøy Municipality. I presented my work and invited horticulturalists to sign up on the interest list. No one wrote their name.

- **Biochar Seminar**, 20th of September 2018, Sandnes Municipality. Seminar for researchers, stakeholders and other interested people on biochar in Sandnes Municipality, and biochar in general. I presented my work so far and invited other stakeholders for a conversation. No stakeholders were interested beyond the ones I already had talked to.

2.5 INTERVIEWING FARMERS

I used an interview guide (appendix 4) and the interviews were recorded on my phone. They lasted about 45 minutes each.

Prior to the interviews, the farmers had signed an agreement consenting to me using the information they shared in the interviews for my thesis (see appendix 3).

Subsequently I transcribed the interviews. All the farmers have been anonymized.

The farmers were:

- **Farmer one** (F1), male. Interviewed in person 3rd September 2018 at his farm in Rennesøy.
- **Farmer two** (F2), male. Interviewed in person 5th of September 2018 at his farm on Ombo Island in Finnøy.
- **Farmer Three** (F3), female. Interviewed in person 8th of October at her farm in Rennesøy.

2.6 Reliability and Validity

To ensure reliability I have described in detail the process I have followed during my research, and therefore if repeated, a similar result could be expected.

To ensure validity I interviewed people as closely related to biochar -- or possible uses of it -- as possible, namely: Scientists, decision makers, and horticultural business owners.

I also had a flexible approach to the interviews. To avoid misunderstandings, I gave a short description of the project to the interviewees before the interviews, so that we had a common ground of understanding.

All information to, and communication with the stakeholders and farmers was in Norwegian. Any quotes used from these conversations in this report I have translated into English.

3 RESULTS

Figure 1 shows a map of the stakeholders I have talked to and how they are connected.

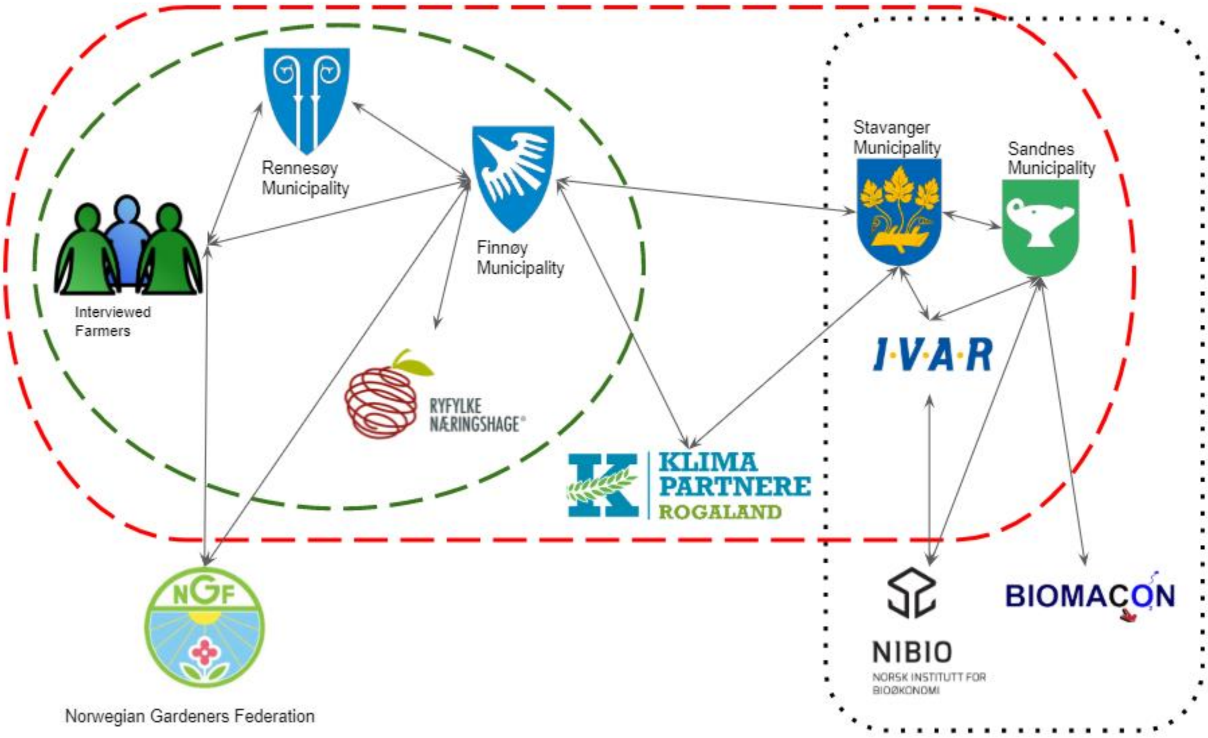

Figure 1: Systems map for stakeholders I have been in contact with for this thesis.

The stakeholders located within Finnøy and Rennesøy Municipalities are found within the green stippled line. Within the red stippled line are the stakeholders located in the Stavanger-region. Outside the red line are the stakeholders located elsewhere nationally, or in the case of BioMaCon - internationally (Germany). Stakeholders working with biochar are within the black dotted line.

3.1 STAKEHOLDERS WHO WORK WITH BIOCHAR

These stakeholders were the starting point of my research (see Network-building and Snowballing p. 13).

3.1.1 IVAR IKS

<u>Biochar Role and Potential Role:</u> Active Role. Inspirator, shares knowledge on the topic, networker. Potential supplier of input material.

<u>Attitude towards Biochar:</u> Positive; thinks it might be important for the region in a few years.

IVAR IKS is an intercommunal water, sewage and waste company in Rogaland, and is partially owned by Sandnes, Stavanger, Finnøy and Rennesøy Municipalities (together with 9 other municipalities). My mentor Rudolf Meissner at IVAR IKS has been involved with the preparations for establishing a biochar/pyrolysis facility in Sandnes, and keeps himself updated on the world of biochar. IVAR IKS are also looking at the possibility of using some of the wooden waste they collect as an input for making biochar, but this is not their main focus. Mr. Meissner acts as an inspirator and sparring partner for the municipalities when it comes to biochar and circular economy, especially since he has good connections with the largest municipalities of IVAR that are already considering biochar as an option, namely Stavanger and Sandnes. He could tell me that biochar is on the rise in Norway, and that Rogaland county might become the first county in Norway with a significant production of biochar due to the interest from Sandnes and Stavanger.

3.1.2 Sandnes Municipality

Biochar Role and Potential Role: Active Role. Municipal biochar-pioneer. Produces biochar from garden and roadside biowaste. First large-scale producer of biochar in Western Norway. Owner of the only BioMaCon pyrolysis unit in Norway. Spreads knowledge of biochar through networking and seminars. Will potentially establish more pyrolysis facilities.

Attitude towards Biochar: Positive; sees biochar as a sustainable and affordable alternative to natural gas and a good way to manage and utilize the waste/bio-resources they have access to from their citizens.

Based on my conversations with Rudolf Meissner it became clear that Sandnes Municipality is the stakeholder of the region who has invested most in biochar. At the time of the start of my research, they were in the process of establishing their pyrolysis facility. Through my conversation with them I learned that their goal is to establish more pyrolysis/biochar facilities and to inspire others to do the same. They estimated a production of 1 big bag of biochar each day and a valued price of NOK 3000 per big bag. They make the biochar from municipal, private garden, and road biomass, and will aim to use the biochar themselves in municipal parks and road structures. They are also interested in distributing to the private gardening and compost market, as well as for research.

3.1.3 Stavanger Municipality

Biochar Role and Potential Role: Active role. Want to work together with Sandnes Municipality and IVAR IKS to start a biochar-project.

Attitude towards Biochar: Positive attitude. Sees it as a way to increase sustainability in the Municipality.

I have not talked to anybody in Stavanger Municipality directly, but they have discussed relevant information with my mentor Mr. Meissner in IVAR IKS who later informed me. In 2016 they sent an application to the Norwegian Environmental Authorities (Miljødirektoratet) in order to obtain support for a pre-project on biochar (Harbo, 2016), which they were granted. This resulted in a report on biochar and ‘green’ district heating (Stavanger Kommune, 2017). In this report they suggested to establish an implementation project using local biomass to heat a building through a pyrolysis unit and using the biochar for soil improvement. They have also added biochar in their municipal plan for climate and environment for 2018-2030. Here they write:

> “The opportunity for production of biochar in connection with greenhouses - that will give ‘climate-negative’ heat production - might be another solution in the future.” (Stavanger Kommune, 2018; p. 38)

3.1.4 NIBIO

Biochar Role and Potential Role: Active role. Researches and advocates for biochar subsidies and projects.

Attitude towards Biochar: Positive. Sees it as a way for capturing carbon and reaching the global and national climate goals for the future.

On a national level, NIBIO is the stakeholder leading most of the research. According to Arne Sæbø at NIBIO Særheim (in Rogaland), they are currently testing biochar for use on roof gardens and its ability to hold water. The results are not yet ready. I also attended a Soil Seminar arranged by Sæbø for the European INTENSE project (Harestad, 2018), where biochar was mentioned by one of the researchers on soil microbiota, Francois Rineau from Hasselt University in Belgium. They had tested biochar in soil over the course of a year with negative results on soil microorganisms. However, he informed me that they had not saturated the biochar with any liquid before applying it to the soil. This research is not yet published.

I have also been in contact with Adam O'Toole as well as Alice Budai at NIBIO Ås regarding their research in the projects CAPTURE +, Carbo- Fertil, and Carbon storage in long- and short-term grasslands. They were the ones taking the initiative for the Norwegian envoy to the IBI Study-Tour to Kaindorf in Austria where I was a participant. There they brought the farmer Bjørge Madsen from Skjærgaarden Farm in Åsgardsstrand. He is reportedly the first Norwegian farmer to make use of biochar, and has been doing so in collaboration with NIBIO (O'Toole, 2018). According to my conversations with them, however, their pyrolysis unit has been out of function most of the time, but that might have changed now.

NIBIO Ås is a driving force for using biochar as carbon storage in Norway and are advocating the implementation of subsidies for soil carbon storing, especially using biochar (Rasse et al., 2018). They are particularly inspired by the Austrian Kaindorf Region and their projects (ibid). Their report on the full potential of using biochar in soils in Norway will be ready in 2021 (NIBIO, 2018).

3.1.5 BioMaCon

Biochar Role and Potential Role: Active role. Manufactures pyrolysis units/biomass boilers.

Attitude towards Biochar: Positive. It is their livelihood.

BioMaCon is a small German manufacturer of pyrolysis units (biomass boilers) in various sizes. Their DECARBO units are made in several sizes, both for homes, farms and industry (BIOMACON, -). The company is owned by Mr. Ulrich Suer who I have been in e-mail contact with. I asked him if he had sold any units to be used in greenhouses, and he informed me that he had sold one to a Belgian biodynamic tomato producer, but that he had no further knowledge on the use of his units in connection with greenhouses. The structure of the DECARBO units are, however, such that they can be directly connected to waterborne heating systems. This is the only manufacturer known to me that has a unit with this function embedded. They are the manufacturers of the unit bought by Sandnes Municipality which is the first functioning pyrolysis unit in the west of Norway.

3.2 Stakeholders who had heard about biochar

There are also stakeholders who are not actively working with biochar, but have some knowledge of it. I reached out to these stakeholders to explore their levels of knowledge and interest, to get a general impression of the 'climate of biochar' in the Rogaland region.

3.2.1 NGF - Norwegian Horticulturalist Federation

Biochar Role and Potential Role: Semi-active role. They are a great source of information and inspiration to the horticulturalists in Norway, and keep them updated on the current status in research, innovations and policies. They have a small section on their websites on biochar, but it is not actively updated.

Attitude towards Biochar: Positive but focuses on other ways of making horticulture more sustainable such as electrification. Little knowledge on biochar.

I had a conversation with one of their representatives and energy advisor, Martin Knoop. He seemed intrigued by what I could tell him about biochar, and I gave him some reading material on the topic. I also had a brief conversation with their other energy advisor Anders Sand on the Tomato Day Seminar, who also seemed interested, but they needed to discuss the topic internally within their organization before making a statement. I have not yet received a statement from them. This is what is written about biochar on their webpage:

> "Free Carbon Capturing. Make coal from forest waste and other plant material. Then plough the coal down into the soil. The technique is well tested and a good alternative to the Mongstad technology." (Sand, -)

3.2.2 Klimapartner Rogaland

Biochar Role and Potential Role: Not active.

Attitude towards Biochar: Positive and intrigued.

Klimapartner Rogaland is a networking member organization run by Rogaland Fylkeskommune (Rogaland County Council). Their goal is to act as advisors on climate issues and to create a regional network to help the transition towards a low-emission society (Klimapartnere Rogaland, -). In my conversation with the leader of the project, Christian Herheim, he seemed intrigued by biochar in connection with greenhouses, especially with the upcoming municipal merge of Stavanger, Rennesøy and Finnøy. He invited me to present my topic on the Working meeting for Sustainability in Horticulture which they co-hosted. He had heard about biochar but had no further knowledge about it.

3.3 Stakeholders not familiar with biochar

The stakeholders that had not been involved with biochar prior to meeting with me were also the stakeholders working within the two municipalities I was researching, namely Finnøy and Rennesøy. Thus, it was necessary both to inform them as best as I could about biochar, as well as getting a deeper insight into their role in the community and their views on sustainability and eco-innovations.

3.3.1 Finnøy Municipality

Biochar Role and Potential Role: No current role. Will, however, be a part of Stavanger Municipality come 1st of January 2020, so this might change. They will likely continue guiding the agricultural activities on the Finnøy and Rennesøy islands.

Attitude towards Biochar: Positive and intrigued, but current focus on biogas and CO2-fees.

Through my conversation with chief of agriculture Silke Ullrich and analysis advisor Marit Magdalene Schweiker, I got insight into the current agricultural activities and sustainability projects in the Finnøy Islands. They arrange meetings and seminars for farmers and businesses and collaborate with Ryfylke Næringshage. They talked about a horticultural industry in decline, with the number of horticulturalist farmers currently at about 30. They also talked about the tense political environment regarding the CO2-fees and restrictions on the use of fossil fuels, the possible restrictions on area for spreading fertilizers (Landbruksdirektoratet, 2018), and how they are working towards the merging with Stavanger Municipality.

They also expressed concern that the biochar might offer competition to the biogas-project currently being developed in Finnøy, and whether the two solutions could co-exist.

3.3.2 Rennesøy Municipality

Biochar Role and Potential Role: Not active.

Attitude towards Biochar: n/a

They did not find it relevant to talk with me but referred to Finnøy Municipality as they are collaborating on agricultural issues.

3.3.3 Ryfylke Næringshage

Biochar Role and Potential Role: No active role.

Attitude towards Biochar: Positive, intrigued, but sceptical in that it might offer a competition to the current biogas projects.

Ryfylke Næringshage (Ryfylke Business Garden) is owned by a mix of public and private actors and is initiated by the Norwegian Ministry of Local Government and Regional Development. Their role is to act as a hub of knowledge and facilitator for so called blue-green development and innovation in the Ryfylke Region.

They collaborate with Finnøy Municipality on their projects. I talked to their CEO Tove Sivertsen and presented my project. She found it interesting and invited me to present my thesis on the upcoming Tomato Day, which is a part of the yearly Tomato Festival in Finnøy. This was a so-called business-political day with a focus on horticultural businesses.

I presented my work there together with politicians, business owners and farmers. My work did not seem to spark a lot of interest though, as the main focus for this meeting was biogas and CO2-fees. One person signed up for my interest list -- a researcher from NIBIO Særheim who is already working a bit with biochar, and only a few helped themselves to an information brochure (I had printed enough for the about 50 participants, and was left with about 45 brochures at the end of the day).

3.3.4 The farmers

I came in contact with two farmers on the 'Working meeting for Sustainability in Horticulture'. They both expressed their negative opinions on CO2-fees and restrictions on natural gas use. The two were initially interested in meeting me for an interview, but then they each cancelled due to busy schedules. These are two of the largest horticultural farms in both Finnøy and Rennesøy, and so it would have been interesting to hear their perspectives.

The three farmers I interviewed are all middle aged, they have many years' experience with gardening, and they are all concerned about sustainability in some way. On the other hand, they have very different farms, environments and practices (see table 3).

Table 3: Comparison between the three farmers and their farms.

Farmer	F1	F2	F3
Gender	Male	Male	Female
Age	Middle-aged	Middle-aged	52
Location	Rennesøy Island, Norway	Ombo Island, Finnøy, Norway	Rennesøy Island, Norway
Type of production	Certified Organic tomatoes, chicken and milking cows	Conventional tomato production; garden plants (garden centre)	Certified organic plants such as herbs, tomatoes, fruits and berries (mostly for decoration). Greenhouse mainly used for events such as wedding, birthdays and seminars.
Size of Greenhouses	2500m2	2800m2 (tomatoes) + 540m2 (garden plants)	1000m2
Landscape	Flat, spacious and open. Surrounded by open fields and a Christmas-tree plantation.	Sloping and closed landscape, surrounded by rocky hills/mountain and forests.	Sloping landscape, surrounded by fields, gardens and forests.
Employees	Yes (no number given)	Yes, 1-5 depending on the season.	Seasonally for weddings
Workload	Full time	Part time (90% retired)	Part time (runs another company)

High-Season	All year	January-June	May-September
Compost	No	No (not enough space)	Not from the greenhouse plants (but plans to), but separate food waste from the events that is collected by the municipality.
Plant-waste management	Pays someone to pick it up	Pile on farm (too expensive to send it for treatment)	Pile on farm
Waste Volume	~ 50 m3 of organic matter + 4 m3 of tomato leaves (per week)	n/a	n/a
Growth medium	Peat moss from Sweden	Coir from Sri Lanka, peat moss from Sweden	Organic soil mix from Sweden (does not know if it is peat moss)
Fertilizer	Manure mixed with water, drip fertilizing. CO2-gas	CO2-gas	n/a
Fuel	Natural Gas	Propane (70-80 tons/year)	Electric heating for events
Buffer tank	No	No	No
Driving factors	Economy, financial security for his family.	Interested in plants, recycling (reuses growth medium to make soil for garden plants and for gardeners), passion for gardening and creating a beautiful garden for visitors/customers to see. Producing quality and trying new methods.	Idealism, permaculture, sustainability, sharing knowledge, eco-tourism, eco-venues, creating alternative workplaces.

Concerns	Workload, economy, time, CO2-fees, restrictions on fossil fuel. Providing a safe income for him and his family.	Food waste, sustainability and resilience. Uncertainty in the tomato-market, competition from the Netherlands. The financial and practical consequences of CO2-fees and restrictions on fossil fuels. Generational shift on the farm.	Sustainability, economy, time. Main focus is to get affordable heating in the greenhouse so that the season for weddings and events can be expanded to the colder months of the year.

When it comes to biochar and their interest in the topic, the answers from the farmers were as follows (see table 4):

Table 4:Comparison of farmers knowledge of, and interest in, biochar.

Farmer	F1	F2	F3
Prior knowledge about biochar	None	None	None
Interested in learning more about biochar	Yes (but learning cannot take a lot of time and energy)	Yes (but learning cannot take a lot of time and energy)	Yes (but learning cannot take a lot of time and energy)
Interested in testing biochar	No, too risky and time consuming. He wants others to do the testing.	Yes	Yes
Interested in producing biochar	Yes, if it is profitable and easy	Yes, if the cost and space demand is within his means	Yes, if it can replace electricity for heating the greenhouse.
Interested in joining a workshop or work group for biochar in the region	No, takes too much time. But interested in study trip to pyrolysis unit in the region.	No, takes too much time and effort. It is difficult for him to travel from the island. Would be interested in an online resource.	Yes, if there is a network already up and running. Prefers a local network but would also be interested in travelling nationally and internationally.

I have also included a summary of the main thoughts and reflections that came up during the interviews (see below).

3.3.4.1 Farmer 1 (F1)

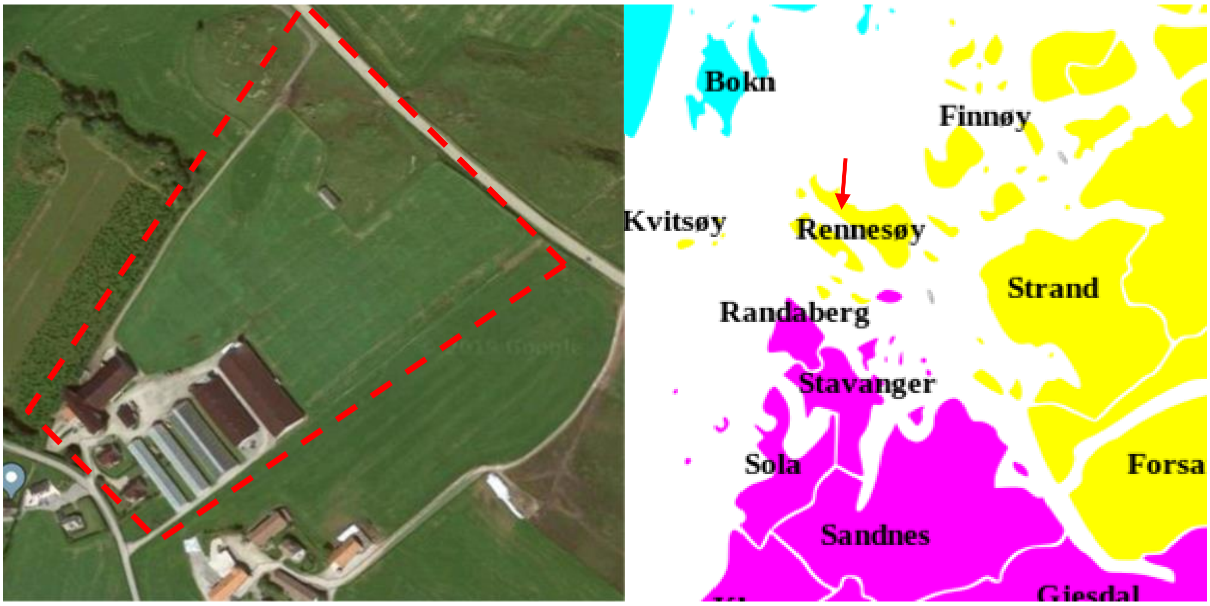

Figure 2: Outline of the farm of farmer 1 (left picture, within the red stippled line). Location of farm on Rennesøy (right picture, indicated by red arrow).

Biochar Role and Potential Role: No current role. Could be a potential producer and consumer of biochar, but not likely to be in the near future.

Attitude towards Biochar: Mostly negative; positive if it can be proven that the risk and workload is low and the profitability and security is high. Infrastructure is not an issue, but access to enough organic matter might be.

This farmer runs a small organic tomato production as well as chicken and milking cows. He sells his organic tomatoes through the COOP-system, and they are distributed to all of Norway (Fylkesmannen i Rogaland, 2016). For fertilization he uses CO2-gas as well as liquid manure from pigs and cows. As pest-control he uses pheromone traps (ibid.)

The farmer has experience with big transitions, he has transitioned from conventional to organic farming some years ago. He says it was a big process with a lot of work, costs and stress that he does not want to go through again. However, he says that if someone else takes the risk of testing the biochar-method, and could show him that it would be worth it to go over to using biochar, he would do it immediately:

> "When we transitioned ten years ago to eco-production, it was extremely much. It was hard to get going. It was hard with production and all things like that so I have it a bit up to my neck to start with new things. And it demands so extremely much, and there are so many mistakes […] that you have to fix, and it [...] costs enormously and it takes so enormously much time. So, I am feeling that […] I need to be sure that I make money. Then I will be a part of it, but I will not do it

> without that. [...] If there [however] is a [biochar] plant up and running, then I am in on it right away."

Space on the farm is also an issue for him - even if the farm is located in a flat and open landscape (figure 3) he does not have much space for neither a pyrolysis unit nor to store input material and biochar on his property.

He is nervous about the transition process currently going on with the CO2-fees and restrictions on fossil fuels that might come, and is concerned about the effect these might have for his farm and economy. He says:

> "The CO2-fee will kill us if we get it. That is without a doubt. It will cost quite a lot. It is not good."

And he says that he would be interested in using pyrolysis as a part of his production if it could be proven that it is cheaper and as easy as the system they have today:

> "If it will be cheaper, then it is easy to change over, no problem. [...] But if I am to be completely honest, I don't think that will happen, because we have too cheap energy. We do. So, I don't think it is easy to compete with propane and natural gas that we are using today."

3.3.4.2 Farmer 2 (F2)

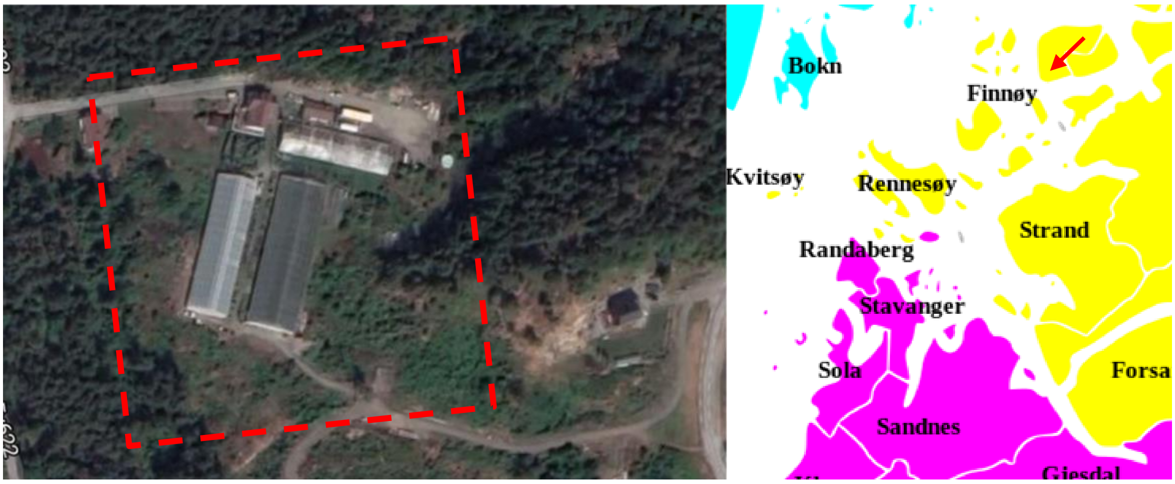

Figure 3:Outline of the farm of farmer 2 (left picture, within the red stipled line). Location of farm in Finnøy (right picture, indicated by red arrow).

<u>Biochar Role and Potential Role:</u> No current role. Could be a potential producer, consumer and distributor of biochar products, but not likely to be in the near future.

<u>Attitude towards Biochar:</u> Positive and intrigued, but not realistic at the moment. Space, finances and infrastructure are limited. Sees potential access to organic matter from his farm and from managing the nearby forests (with the added benefit of preventing forest fires).

This farmer produces conventional tomatoes and some cucumbers, but his real passion is his garden plants. He grows every plant - including the tomatoes - from seed himself. He imports coconut fibres (coir) from Sri Lanka that he uses for growing the tomatoes. This material is then reused for growing the garden plants. He has developed his own soil mix based on the re-used coir, that he also sells to his customers.

At the time of the interview he had one employee tending to the tomatoes, and he himself was busy looking after the garden plants and developing a visitor's garden on his farm. He says his farm is popular amongst the locals as well as the holiday guests that visit the many cabins on the island. Through his garden his goal is to inspire the visitors to create beautiful gardens of their own.

He is motivated by challenges and likes inventing his own technical solutions. He is therefore intrigued by the biochar concept and was giving his reflections on how this might fit in on his farm. Especially interesting was the use of biochar as a growth medium as this could eliminate the imported coir. He would be willing to develop and test this growth medium himself if he was given access to relatively cheap biochar. In the long run he would also be interested in testing a pyrolysis unit for heat and CO2 as well, but the cost of such a system is likely too high.

Space is also an issue, his farm is cramped between a road, a small mountain and forest on three sides. The space is already used up by the buildings and the park (see figure 3),

He raises questions on the sustainability of his tomato production, stating that it is costly and labour intense to transport the tomatoes from the small island. He is the co-owner of a local packery for tomatoes, however, he says that 2018 was a bad year in terms of selling the tomatoes. They had to throw away large parts of their production. He says:

> "The way it was now this summer, this has happened before as well. They [Dutch farmers] must pay to get rid of the surplus tomatoes - it is a waste problem [...] So it is cheaper to send them to Norway, because that market means nothing to them. They cannot dump their produce in France or Germany because then they will destroy their own market. But to dump the produce in Norway, kind of, does not matter a thing [to them]. But it means a lot to us. And the wholesalers [...] if they have bought cheap tomatoes in Holland, they would prefer to sell them before ours, right? Because then our tomatoes are left in the storage, and our tomatoes are our own responsibility almost until they are sold in the store. And then we have a problem."

He also says that the summers usually is a problematic time in terms of selling their tomatoes, and he reflects on the sustainability of tomato production in Norway. He highlights the challenges of producing tomatoes, comparing it to salad and cabbages that are quicker to grow:

> "[...] the problem is that it is a production that goes over so many months, it is not like salad and cabbage that you kind of harvest after some weeks. And therefore, you get a little different challenges. And then all production is coming to a peak in the middle of summer. Yes, so it is not easy this. That is for sure."

He also highlights the challenges of living on a small island connected to the mainland only by boat:

> "We have a challenge us who live on an island, in the outskirts of Stavanger - future Stavanger Municipality. We will be the absolute utmost point of Stavanger Municipality. [...] I cannot throw myself in to the car to deliver produce after two hours like they can do in Jæren for example. We have many challenges that others do not think about."

3.3.4.3 Farmer 3 (F3)

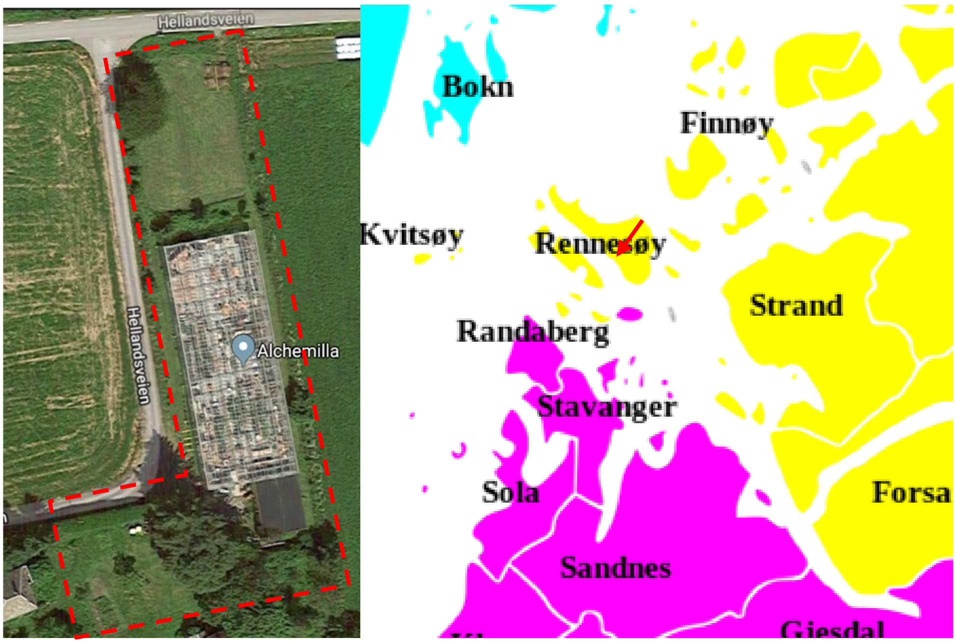

Figure 4: Outline of the farm of farmer 3 (left picture, within the red stipled line). Location of farm on Rennesøy (right picture, indicated by red arrow).

<u>Biochar Role and Potential Role:</u> No current role. Could be a potential producer, consumer and distributor of biochar.

<u>Attitude towards Biochar:</u> Positive and interested. Sees it as a potential way of increasing the sustainability, economy and providing heating for the greenhouse. Wants more knowledge on biochar but has limited time and energy to acquire this knowledge.

This farmer has made use of a closed down tomato greenhouse to start her permaculture and event business. She employs the help of another neighbouring business that grows organic herbs, to grow organic plants in the greenhouse. These have an organic Debio-certification.

The farmers main business is her garden and landscaping business that she also makes use of in the greenhouse. The greenhouse then is quite unconventional, with hammocks and sand, and a stage and sofas and olive trees and a lot of aromatic herbs and flowers, in addition to the space for about 150 guests.

Every spring and summer season the last years, the greenhouse has been occupied by wedding guests and couples wanting to celebrate their union there in the weekends. In the weekdays the greenhouse is used as an office, and sometimes let out to parties and events. They are in the process of building a kitchen for food preparation too, to be able to offer food from the greenhouse and the local area to the guests.

Permaculture is one of the key principles of the business, and the farmer puts equal weight on the three pillars of permaculture:

> "So [it is that] that we are appreciating it in an equal-sided triangle: The human, ecology and economy. That is our idea, yes. So, in permaculture there is kind of a main mantra that I often think about, that is: "What's my problem? That's the solution." And that about energy is something that worries me. In comparison to, right, that we will be here the whole or parts of the year. Like the season is from 1st of May through September. And: How could we stretch that season through having heating for example."

She reflected on biochar production as a way to extend the season in the greenhouse, providing heating and a growth medium. This would likely improve the economy of the business, as well as closing the loops in terms of heat and soil use. She namely says she wants to test biochar in the greenhouse:

> "I am thinking about that thing about making soil, that is important for the Earth. So, if we can start with using it here, and produce our own soil and fertilizer [...] that would be nice."

This farmer is positive in terms of providing space for a pyrolysis unit, even if she has the smallest farm out of the three farmers (see figure 4). She already operates on rented land and has a vision to expand her business to include other closed-down greenhouses and fields in the area. That could also provide more input plant material to run a biochar-production.

4 Discussion

As described in the introduction I had two questions entering into this endeavour: One related to biochar technologies in general, and their potential role in helping rural communities to transition away from fossil-based inputs. The other related to greenhouse horticulture in particular, and the current possibilities and limitations for adopting biochar technologies into this industry.

Using horticulture in Finnøy and Rennesøy as an example, I also had several assumptions about biochar and its potential role for the Stavanger Region, as described in Methods and Materials (p.12).

4.1 Biochar Pyrolysis Technologies as Alternatives to Fossil Based Technologies

suggested that one way forward for biochar pyrolysis technologies as tools for climate mitigation, is to promote the application of it in particular **niches**. From there the potential of biochar can be demonstrated and broader applications may be identified (ibid.).

The results show that one viable niche is to use biochar-technology as a **direct replacement for some fossil-based products**. This is demonstrated by Sandnes Municipality (see Results page 16) where they have replaced one of their natural gas tanks for **water-borne heating** in one of their buildings, with a pyrolysis biochar facility. So far it seems to be doing well in terms of heat and biochar production, although recently there have been some issues with the feeding mechanism of the system, halting the production. This will likely be sorted out soon.

Similar water-borne heating systems are common in commercial greenhouses - all three farmers have water-borne heating installed in their greenhouses, though only farmer one and two are currently using them. Such systems are especially suitable for use with renewable energy sources (Klima- og forurensningsdirektoratet, 2010).

Sandnes Municipality, as well as Stavanger Municipality once they get their first biochar facility, are planning to use the biochar made from garden and park waste as a **growth medium** in their park-and road structures. This will in many cases **replace peat-based media**. This approach is modelled on the city of Stockholm, Sweden, where they have a similar system (Nordregio, 2018). In this way biochar can make these municipalities less reliant on fossil inputs.

Sandnes Municipality is open to collaborate with farmers on biochar production and use. This is interesting because both farmers one and two are dependent on cheap peat-based growth-medium in their tomato production. Farmer one would be willing to try an alternative growth medium given that the price would be the same as for peat, and farmer two and three have expressed an interest in experimenting with biochar mediums.

This is an opportunity for the municipalities to test their biochar in an agricultural context as well. Through using local waste-based biochar in a growth-medium product, the need to purchase these products and transport them from for example Sweden (in the case of all three farmers) or Sri Lanka (in the case of farmer two) is reduced. Should the results from such testing be positive, this could contribute to reaching the goal of a carbon neutral horticultural industry in Rogaland.

As described in the results, researchers atNIBIO Særheim are also experimenting with biochar in Rogaland, and are testing its capacity to **retain water** in green roofs and in planted walls. The results of this research are not yet concluded, but they might offer additional uses for biochar in this rainy region. Increasing the water-retention in for example soil, indirectly reduces the need for fossil inputs through reducing the need for fertilizers as the soil is not being depleted of nutrients so quickly, and fewer resources are needed in managing the excess runoff water. Depending on the kind of biochar, it may increase the water retention capacity of the soil with up to 20% (Bartocci et al., 2017).

Runoff of potentially polluted water is a concern for the horticultural industry, as farmer two mentioned. He is concerned that the demands regarding runoff from the greenhouses will be stricter in the future. As he has older greenhouses and limited space on his farm, he can not afford to make large alterations to his facilities. Adding biochar to the soil in or around the greenhouses might be a low-tech, low-impact way of managing such runoffs.

In addition, this technology is also a way to **manage waste in a circular system**, and this is a goal for both Sandnes and Stavanger Municipality. This is where IVAR IKS comes in as a stakeholder, as they manage most of the municipal waste of the region. They are looking at ways of utilizing the waste in circular and sustainable ways, and biochar has thus sparked their interest.

As for the farmers I spoke with, farmers two and three had no particular waste management system for the excess plant biomass from their greenhouses. Farmer one paid to send his waste for treatment, but he did not know where it went. It is also worth noting that none of the stakeholders had any information on the amount of waste from the horticultural industry in Finnøy and Rennesøy, and what they generally do with it. There are no specific guidelines for how untreated waste from the greenhouses should be stored other than an urge to avoid water contamination – it is up to the municipalities to check that the waste is stored satisfactorily (Mattilsynet, 2016).

Using the excess biomass from the farms for biochar production, either in a farm-scale or larger-scale system, would help **closing the loops** on the farms. There is also an international project called Horti-BlueC looking at how to do this. They are researching the potential for upcycling CO_2 emitted by greenhouse heating installations, spent growing media (as feedstock for biochar), green waste (as feedstock for biochar) and plant fibers for soilless cultivation (Horti-BlueC, -). Their research will be concluded in 2021, and their results might have an impact on the future of agricultural waste-management in Norwegian horticulture.

Biochar has also proven to be a way of **enhancing the value** of the waste resources, as it is a high-value product. There seems to be a market for this biochar in the region, and Sandnes Municipality reports that all the biochar they will produce the next two years has been pre-ordered for various uses. Strengthening such a market with such a high-value product will likely motivate others to adopt the same technology, and through that reduce the use of fossil-based technologies.

It is also noteworthy that, according to Schmidt (2013), there is an **unknown number of uses** for biochar, and biochar is already being used for other purposes other places in the world, such as: Feed supplement for farm animals for improved health; use in the building sector as building material, in paint, or for decontamination; water-treatment; in packaging; as filters; in medicine; in textiles; and in beauty products. These uses reduce the need for many fossil inputs, and their existence strengthens the claim that there could be a larger market for biochar also in Norway.

4.1.1 Comparing Biochar to Other Relevant Non-Fossil Alternatives

The use of petroleum products is the largest source of CO_2 emissions in the Norwegian horticultural production – these emissions would be greatly reduced through the use of renewable energy sources, with the use of electricity being the most effective measure (Verheul & Thorsen, 2010). Electrification is also promoted by NGF (see Results) but is not a likely option for Finnøy and Rennesøy, because they are island municipalities, and upgrading the electric grid to meet the needs of the horticultural industry would likely be too costly.

4.1.1.1 Biogas

To eliminate the need for fossil energy, an alternative technology that was mentioned by several of the stakeholders was biogas. IVAR IKS, for example, has a large biogas-facility in the region (Grødaland); and in Finnøy, a project called Biogass Finnøy AS -- supported by Finnøy Municipality, Ryfylke Næringshage and Rogaland County Council -- are looking at biogas as an option.

The biogas project in Finnøy and Rennesøy is still in the planning phases and has been so the last 10 years, however they recently got a grant to make a report on the possibilities for the use of this technology (Flesjå, 2019). In this project they are hoping to use manure from animal husbandry, fish-waste from aquaculture, and plant-waste from horticulture to make biogas, and use the biogas to fuel the ferries in the municipality as well as heating greenhouses (Nordmark, 2018).

The potential for making biogas out of manure in Rogaland County is high (Carbon Limits, 2018), and with so much time and energy invested in the biogas project it is probably not unnatural that the interest with participating in my project has been so low. Especially not if they see biochar as a competition to the current biogas-project, which was a concern mentioned by Finnøy Municipality in my conversation with them.

I argue however that given the high energy-demand of the area due to the horticultural industry, they would benefit from also looking at other alternative solutions such as biochar. This in order to avoid a 'biogas lock-in'. Following the conclusions of (Klitkou et al., 2015), giving one technology a leading role gives this technology an advantage over newer technology - even if the former might not necessarily be the better solution. This is however also not necessarily bad:

> "We observe that the lock-in mechanisms favouring mature renewable energy trajectories can reinforce radically new technology trajectories [...]. However, new paths can act as barriers to other more radical paths because they bind financial or physical resources." (Klitkou et al., 2015)

We can then imagine that the establishment of biogas-production -- which can be characterized as a mature renewable energy trajectory[4] -- in Finnøy and Rennesøy might pave the way for biochar in the future, even if it is currently taking up the financial, physical and political resources that biochar-production would need in order to mature.

The two technologies might even be complementary: Biochar could have the potential to increase the biogas output when mixed in to the biogas-substrate ((Meyer-Kohlstock et al., 2016); (Jang et al., 2017)), and can also be made from the fermentation residues from the biogas plants (Conte et al., 2015).

When based on plant-materials biochar could be safe for consumption by cattle, and be added to the feed or bedding for potential health benefits for the animals – an estimated 90 % of the biochar produced in Europe are being used for such livestock farming purposes (Gerlach & Schmidt, 2014). Through this, biochar ends up in the manure, which then again can have an increased biogas output – a so called cascading effect. This way the agricultural cycles of organic matter can become more closed.

In addition, it would be possible to use other resources that are currently not being planned as input for the biogas, such as forestry products, to produce the biochar. Farmer two was especially positive towards this idea, highlighting the added benefit of better forest management to prevent forest fires.

Forest fires contribute to global warming through the large amount of CO2 being released to the atmosphere. It is unsure what the future will be in terms of forest fires in Norway, but longer drought-periods (such as seen in the summer of 2018) and higher temperatures, will increase the frequency and size of such fires ((Direktoratet for samfunnssikkerhet og beredskap, 2008); (Tveito, 2014)).

4.1.1.2 Sawdust and Woodchip Stoves

As another alternative, forestry products such as sawdust and woodchips, can be used to fuel sawdust and woodchip stoves. Such stoves are also compatible with water-borne heating systems, and is an alternative considered both by farmer two and Sandnes Municipality. However, the burning of sawdust produces ash which does not have the same potential to be used for carbon-storage that biochar has. Sawdust/woodchip stoves are however a more mature technology than pyrolysis biochar systems.

Sandnes Municipality found the pyrolysis-biochar system more appealing, and farmer two found that the sawdust-technology was too expensive and space-demanding considering the need for an additional buffer tank to go with the system. Such a buffer tank for storing heat will likely be necessary with a pyrolysis system as well.

[4] As an example: A search for “biogass” (biogas) currently gives about 301 000 results on Google, “biogass Norge” (biogas Norway) gives about 166 000 results, and “biogass Rogaland” gives 50 300 results. In comparison a search for “biokull” (biochar) gives 22 200 results, “biokull Norge” (biochar Norway) gives 19 800 results, and a s search for “biokull Rogaland” gives about 4600 results. “Biogas” gives 20 900 000 results, while “biochar” gives 2 310 000 results. This indicates that biogas is more mature as a technology and concept than biochar.

4.1.2 BioCCS: Biochar as a Carbon Sink

As mentioned in the introduction, one of the main attractions with biochar in terms of reducing GHG-emissions is its potential role in **carbon capturing and storage (CCS)**. The goals of phasing out all use of fossil energy in the Norwegian greenhouse industry, and making the greenhouse production in Rogaland carbon neutral are ambitious. In addition to cutting out the use of fossil fuels, biochar and BioCCS might be the way to go to achieve these goals.

Sørensen and Ellingsen (2011) estimated a CO2-reduction from digging down biochar in Norway to about 1060 kg CO2 per ton of biomass.

However, with research still being unconcluded on the safety of digging down large amounts of biochar into Norwegian soil, it is unlikely that this will be implemented on a regional scale in the near future.

4.2 Current Prerequisites, Limitations, Enabling Factors and Possibilities for Adopting Biochar-Technologies in to Horticulture in Finnøy and Rennesøy

According to Thomassen et al. (2017), there are several roles farmers can have in a biochar system either as consumers, producers or both (see figure 7).

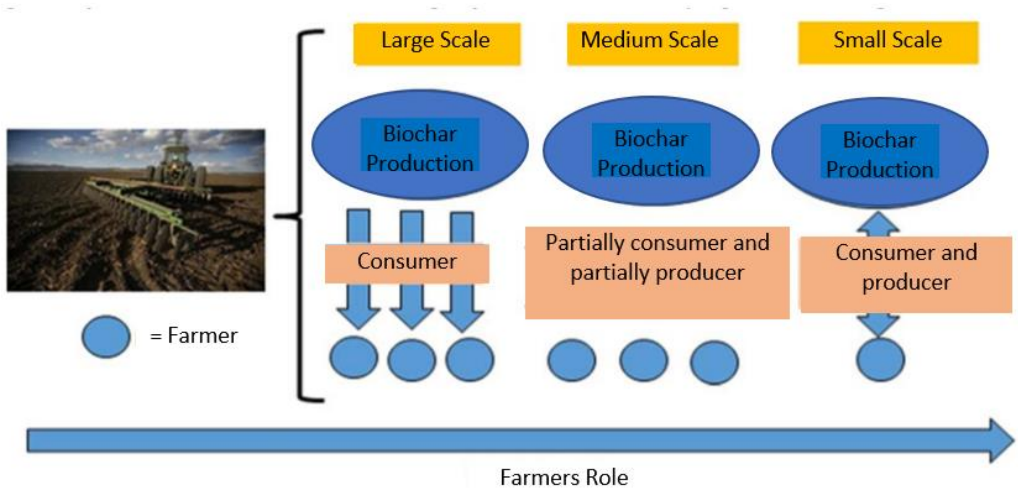

Figure 5: Farmers potential roles in a biochar-system on a large, medium and small scale. Adapted from Thomassen et al (2017, figure 9, page 19)

Thomassen et al. (2017) further described a large-scale biochar system as one that takes advantage of the already existing facilities, knowledge, and competency of current large-scale industries; and a small-scale biochar system as one that uses resources and simple technology already available on the farms. According to Phillips et al. (2018) smaller farm-scale biochar systems utilizing local agricultural waste for energy production for the farm may even be more energy efficient than larger, regional systems.

More research is needed in order to say if this is true for the Stavanger Region. Yet there are enabling factors that make such small-scale facilities possible as a solution for Horticulture in Finnøy and Rennesøy. There are however several prerequisites and limiting factors as well.

4.2.1 Prerequisites

The results show that, in order to find meaning and security in their work, the three farmers depend on several needs being met by the inputs and outputs on their farms (see table 5).

Table 5: The interviewed farmers technical, economical and agroecological needs for their farms to be a meaningful and secure workplace.

Technical Needs	Economical Needs	Agroecological Needs
Energy for heat	Predictable income	Predictable and stable market
CO2 for fertilization (F1 and F2)	Sufficient funding	Favourable policies
Material for growth medium		Sustainability
Input material/feedstock		Productivity and good quality products
Enough space for the technology		A network for sharing and learning
A system for repairs and technical guidance		Enough time to manage the system
		Social Equity

For biochar pyrolysis technologies to be a desirable solution for the three farmers, some or all these prerequisites need to be met. This is in line with what Thomassen et al. (2017) listed as important factors for implementing biochar, namely: Financial gain for the farmers; available extension services; the possibility for the farmers to learn about, seeing and experiencing biochar; trust; a low risk for the farmers; and access to high quality biomass.

4.2.2 Limiting Factors

Salo (2018) identified several challenges for adopting biochar production technologies: lack of practical research results; the variations in biochar quality and types; low public awareness; unclear definition of biochar; few options for external funding for biochar producers; and the need for sophisticated yet affordable technology. I argue that these challenges are valid also in the Stavanger Region. Based on the results I have identified a few other limitations as well.

As pointed out by farmer two, tomato production in Finnøy/Rennesøy is not a sustainable industry in that it is dependent on fossil fuels for heating and fertilization; transportation is often difficult and costly due to the decentral location; the tomato-market is unstable; there is a high competition from abroad; and often large amounts of tomatoes are going to waste because the market is saturated before their tomatoes are sold. Also, tomato-production is a challenging one in that it takes much longer to produce a tomato than for example a salad, and that makes it more difficult for the farmers to predict the demands of the market.

4.2.2.1 Space Requirements

Depending on the system and the type of biomass input, a pyrolysis biochar system requires a lot of space. In Sandnes the system takes up the space of about three medium sized shipping containers, in addition to the buffer tank, and storage and drying area for biomass. None of the farmers currently had much space to spare for such a system. Farmer two had the most challenging landscape in terms of this, being located on in a slope in between rocky and forested hills. The landscapes of farmer one and three were flatter and offered more possibility of such an expansion. This factor might offer challenges in implementing some smaller farm-scale pyrolysis systems[5].

4.2.2.2 Costs

The three farmers all mentioned costs and financial risk as one of the main concerns in making use of biochar technologies. Innovasjon Norge [Innovation Norway] do, however, offer financial support for farmers wanting to invest in pyrolysis technology (Innovasjon Norge, -), and both farmer one and three were positive towards investing in a biochar pyrolysis system, as long as it could be proven to them that the system would meet their needs. When it comes to the actual price for a pyrolysis system, this would depend on the energy needs, budget and space availability of the farms. It is not within the scope of this report to make such calculations, as they would need to be done on a case-to-case basis.

Sørensen and Ellingsen (2011) did, however, make some estimates on the costs of biochar technology in Norway. They concluded that the costs of producing and storing 1000 kg pure carbon biochar will cost about NOK 2450. They further conclude that in order for this to be profitable for farmers, funding is needed – for example NOK 2000 per ton pure carbon biochar put in to soil.

Sandnes Municipality have based their budget on the following costs: NOK 0.41 per kWh for heat energy, and NOK 3255 per 1000 kg produced biochar. In other parts of Europe, we can find selling-prices of about EUR 600/1000 kg pure biochar, EUR 1000/1000 kg feed-grade biochar, and EUR 1500/1000 kg biochar-based active char. In the future there might also be support-schemes for carbon storage (Skinnes, 2018) which could have positive impact on the calculations.

4.2.2.3 Noise

Although no testing has yet been done on sound pollution from the biochar facility in Sandnes, it is safe to say that their pyrolizer is not a quiet machine. Farmer three in particular mentioned noise as a disadvantage, considering the neighbouring pig-farm and their need for quiet surroundings, as well as the greenhouse being used for events. This is also something that needs to be taken into consideration, depending on the farmers preferences and needs. Especially given that all three farmers currently are using silent heating systems (gas and electricity).

4.2.2.4 CO2 for Fertilization

When it comes to the technical prerequisites, **CO2** is currently a limiting factor. The current system of farmer one and two use fossil fuels -- natural gas and propane respectively -- and

[5] An exception to this is so called kilns for biochar production. These are small barrel-like systems for burning biomass. These are limited to biochar production only, however there are also stove-like alternatives that could offer heat a well.

they are dependent on the CO_2 produced in the burning of these fuels to produce enough crops. Farmer one said:

> "When we burn natural gas today, we get a lot of CO_2 that we have an extreme need for. If I were to cut that out, I would need another CO_2-source. It costs to buy pure CO_2 in tanks."

Vermeulen (2014) emphasized the need for the gas-input in the greenhouses to be as pure as possible, lest the sensitive crops will be damaged.

Whether or not the CO_2-containing exhaust produced in a pyrolysis-biochar system would be suitable for that purpose is uncertain and is something that would need to be tested. The representatives for Sandnes Municipality have expressed a willingness to test the quality of the exhaust from their pyrolysis unit with different input materials. The Horti-BlueC-project will also likely give some conclusions on that matter. Yet, Mr. Suer from BioMaCon mentioned to me that he has sold a pyrolysis unit to a Belgian tomato farmer that seems to have success using the exhaust for fertilization -- that is an indication that the technology might also be used for this purpose.

4.2.2.5 Time

Time is a limited, non-renewable resource, which the farmers carefully use where it is most needed. All three of the farmers were sceptical to the fact that a biochar system might take more time and effort than their current system. The current systems of electricity, natural gas and propane are relatively effortless to handle – they just have to "flip a switch" to turn it on and get heat almost instantly. With a pyrolysis-system this will involve loading input for the fertilizer, and removing the biochar at the end of the process. This kind of system also requires a lot more knowledge than the current system, and the farmers would need to take time that they do not necessarily have, to learn about it.

Using biochar in a growth-medium however, might not necessarily take more time than the current solution using peat.

4.2.3 Enabling Factors

As discussed, biochar already has a role in the Stavanger Region within the six previously identified niches: heat-production; growth-medium; peat replacement; water-retention; waste-management; and waste enhancement. There are also a few more enabling factors for implementing biochar technologies in the horticulture of Finnøy and Rennesøy.

4.2.3.1 CO2-Fees

The current Norwegian government are working towards implementing a flat fee on CO_2-emissions for all sectors including agriculture (Statministerens kontor, 2018). Both farmer one and farmer two, as well as the farmers presenting on the seminars, expressed massive concerns that if such a fee is introduced, it would mean the end of their tomato-production.

If the tomato industry would disappear from the region due to this, one of the corner-industries of the Stavanger Region would be gone. Transitioning to renewable energy-sources such as biogas and biochar might prevent such a downfall. Thus, a CO_2-fee might be an enabling factor and motivation for adopting biochar in this case.

4.2.3.2 Market Potential
Sandnes Municipality has no problem getting rid of their biochar, and as discussed earlier, there are likely multiple market niches for biochar products.

4.2.3.3 Diversified Farms
All three farmers have diversified their production. This means the farmers have more than one income to lean on. This is an advantage, as farm diversification has the potential to enhance the resilience of the farm and food systems (Valencia et al., 2019).

4.2.3.4 Focus on Sustainability and Open to New Methods
Thomassen et al. (2017) suggested that farmers that are concerned about sustainability might be a favourable target-group for the first phases of implementing biochar technologies in Norway, because they tend to have an agroecological perspective of their farms. The three interviewed farmers all seem to fall into this category, with farmer two and farmer three having the strongest interest in sustainability out of the three, and an interest to test biochar technologies for themselves. Farmer two said:

> "But it is my interest in plants that is the reason I am here – not the tomatoes. It is to make some things that others are not producing and to have the opportunity to test new things. Try new products."

4.2.3.5 Existing Knowledge-Base in the Region
Sandnes and NIBIO are building knowledge on the use of biochar, this will be a benefit for later adopters of this technology in the region. Especially since both are already involved with sharing information about biochar to a wider public.

4.2.3.6 Biogas
Biogas is, as mentioned, the main focus in terms of alternative energy sources in Finnøy and Rennesøy. Being a more mature technology in the region, and possibly being compatible with biochar, it might pave the way for also adopting biochar-technologies in the future.

4.2.3.7 Existing Infrastructure
The three farms, and likely most of the greenhouses in the area, all already have biochar-compatible water-borne heating systems installed. Some might also have a buffer tank for storing warm water which would be necessary in order to get a table supply of heat.

4.3 The Way Forward For Biochar in Horticulture in the Stavanger Region
It is not impossible that pyrolysis biochar technologies could be a part of increasing the sustainability of the horticultural industry in Finnøy and Rennesøy, and in Rogaland County at large. If such a route is chosen, the farmers roles will, at least initially, likely be as consumers of biochar, with Sandnes Municipality being a larger scale producer.

4.3.1 Networking
Figure 1 show that there is not a strong communication between the stakeholders involved with biochar, and the stakeholders involved with horticulture in Finnøy and Rennesøy. Yet, if

we want biochar technologies to be a part of Norwegian agriculture on a larger scale, there is a need for a wider sharing of knowledge on biochar with farmers and other stakeholders in Norway.

To help with that NIBIO, together with four other stakeholders, recently established the Norwegian Biochar Network (O'Toole, 2019). The goal of the network is to gather stakeholders from the biochar value-chain in Norway, promote biochar as an important part of the circular bio-economy, and work towards Norway becoming a leading producer and utiliser of biochar (Norsk Biokullnettverk, -). Currently none of the biochar-stakeholders in the Stavanger-Region are members of this network.

Yet there is a willingness to spread information about biochar in the region, with both Sandnes Municipality, IVAR IKS and NIBIO Særheim being active spokespersons for the technology on various seminars and meetings. NIBIO is involved with horticulturalists in the region, but one of the more important organizations for the farmers seemed to be the Norwegian Gardeners Federation (NGF). This organization does currently not share a lot about biochar to its members.

NGF do however keep themselves updated on trends and research going on more internationally, so perhaps they will look closer at biochar when more specific research, such as the Horti-BlueC-project is concluded.

4.3.2 Farmer Recruitment

Looking back at the assumptions made at the beginning of this project, biochar is a potential tool for the horticultural industry, as well as a potential way of creating jobs and resiliency in the region, but the interest in it is currently low. My trying to contact the farmers in summer and fall, which is the busiest period of the year for the farmers, was likely a contributing factor to this. Farmer two puts it this way:

> "I tell those who arrange courses and things like that, that «Do not bring in too [many meetings] from March until October» because most [horticultural farmers] have more than enough – at least those [of us] who are devoted."

This will also explain the low recruitment of farmers seen at the seminars I attended.

Knowing what I know now about the situation in Finnøy and Rennesøy, I would have focused the information leaflet I sent to the farmers on biogas and how biochar might be compatible with it. Also, I would have focused more on biochar as an alternative to peat-based growth mediums. I think that approach would have sparked more interest. In recruiting the farmers, it would also have been beneficial with a closer collaboration with the NGF, which seems to be the main channel for spreading horticultural news and information in Norway.

4.3.3 Further Research Questions

In order to develop the idea of using biochar pyrolysis technologies for heat, growth-medium, and CO2-fertilization in horticulture in the region, there are still some questions needing answers.

- How much biomass is available in the region, and what kinds of biomass?
- What is the quality of the CO_2 produced from this biomass, and is it pure enough to be used in greenhouses for fertilization?
- What are the total costs, space demands, time demands, and knowledge demands of a pyrolysis-biochar system in connection with horticulture?
- Is the quality of biochar growth-media good enough to replace peat-based media?

5 Conclusions

Biochar has the potential to replace several fossil-based inputs in the Stavanger Region, as is demonstrated by Sandnes Municipality. The five niches: heat-production, peat replacement, water-retention, waste-management, and waste enhancement are currently the main uses of biochar in the region.

Horticulture in Finnøy and Rennesøy may be another niche, and a starting point for the implementation of biochar technologies in Norwegian agriculture. Some prerequisites need to be fulfilled in terms of ensuring a low risk, predictable, pleasant and stable working-place for the farmers. The main enabling factors for fulfilling these prerequisites are: the government pushing for change in the industry through implementation of fees on CO_2-emissions and restrictions on the use of fossil inputs; diversified farms; farmers open towards sustainability and innovation; an existing knowledge base on biochar in the region; biogas possibly paving the way for other technologies; and compatible technology already existing on the farms.

However, the main limiting factors for this are: limited space for expansion of the farms; high costs connected to pyrolysis systems; a need for pure CO_2-gas for fertilization; and busy farmers with limited time to spend on learning a new technology.

Developing the ideas and implementation of biochar in Norwegian greenhouse horticulture further could contribute to reaching the goals of a carbon-neutral horticultural industry. This would in turn reduce the environmental footprint of the Norwegian agriculture, and help Norway comply to its commitments in the Paris Agreement. Yet some practical questions still remain unanswered, some which will likely be answered once ongoing national and international research projects reach their conclusions within the next few years. Time and crisis, however, waits for no man. Given the positive responses from two of the farmers as well as the main biochar stakeholder in the region (Sandnes Municipality), there is a foundation already for testing this technology in horticulture in this important region relatively soon.

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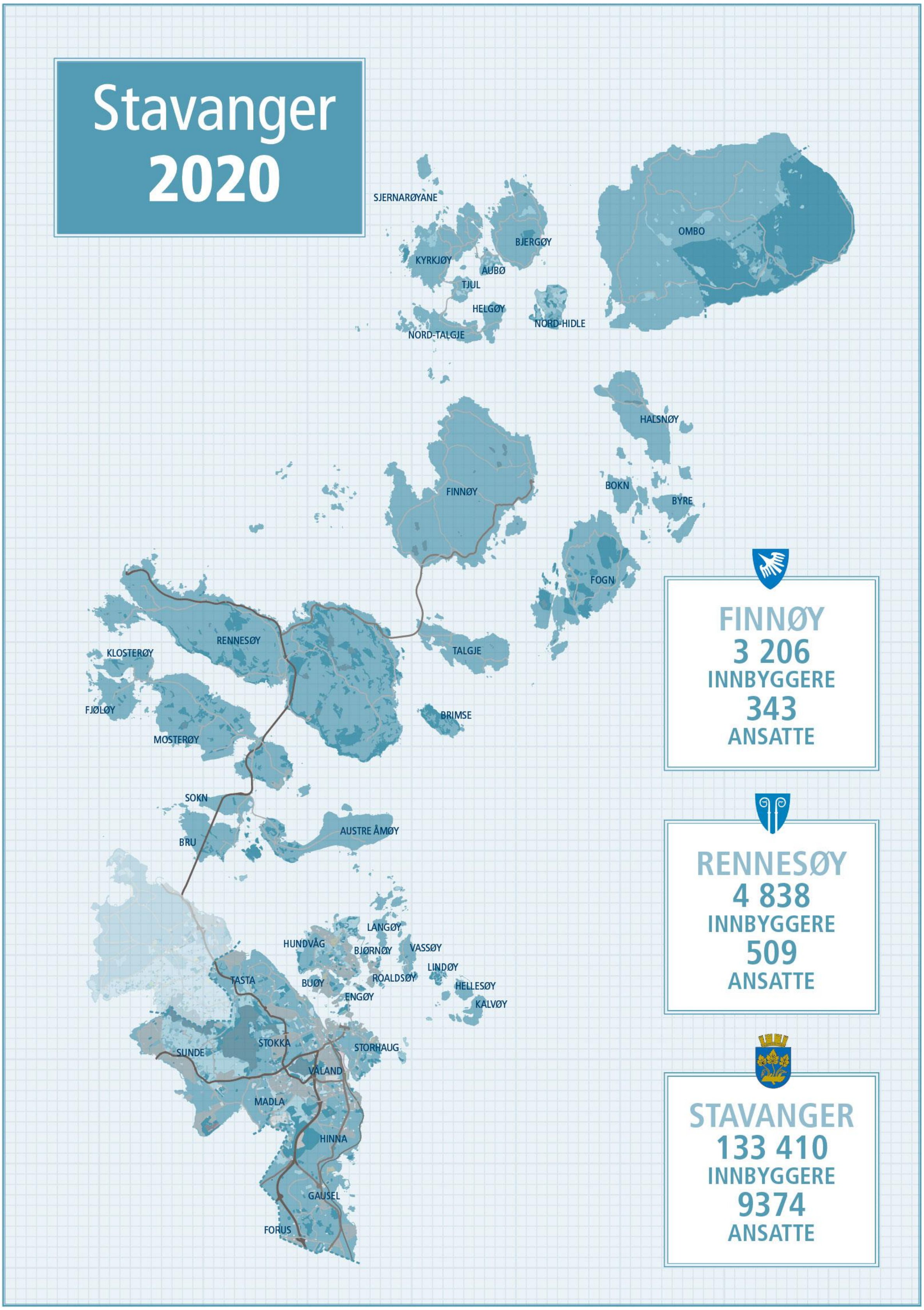
7 LIST OF APPENDICES

Appendix 1: Map over 'New Stavanger Municipality' (Nye Stavanger kommune, -).



My Reflections

Reflecting on this process, the first thing that hits me is the low number of farmers willing to participate in my study despite my efforts trying to recruit them. Frankly, I have spent (and wasted) some time with being disappointed that I was able to spark so little interest. There is however a value in small samples and in-depth interviews as well -- it puts the focus on the human factor of a situation. I hope that perspective shines through in this report.

Having started the masters programme in 2013, finishing now in 2019 is also a bittersweet experience. But life for most is a bittersweet dish – it would not be the same without a serving of juicy challenges on the side. Another necessary ingredient is friendship, and I am grateful for the friends I have met through this programme and all the experiences and action-learning we have shared together over the years. With these daring and caring people in my life I am well-equipped to face the next chapters of my life.

If I could do it over again, I would have made sure to involve these peers more into my process, and perhaps it would also have been wise to write the report in collaboration with another student. Because, I will admit, writing and working alone outside of a peer-situation has been quite challenging.

The chance to work as an intern at IVAR IKS has been a life-changing one, as I am now clearer on what kind of job-situation I want for my future. I would highly recommend such an internship for anyone looking for more hands-on experience. The exchange I had to ISARA-Lyon in 2014 is also an experience I can recommend – especially given that as a Norwegian student at the NMBU Agroecology programme, the second semester in Norway was at the time also a lonely one given that almost all the classmates had left Ås. It was great having the opportunity to spend some more time with my peers in France. On the other side, with me coming from a non-agronomical background, the semester in France was not without its challenges.

Patience and compassion with other people as well as with myself have been the most profound lessons of this journey. No matter how our good our intentions are, in order to "save the world" (and ourselves) patience and compassion are crucial. Nothing good comes from forcing ideas or solutions on anyone.

I would, for example, of course prefer that this report was a flawless one. I have however needed to humbly admit my limitations and accept that in my case, as in anyone else's, "good enough" is more than enough.

I wish us all the best of life and love,
Eva Karén Karachristianidis

Appendix 3: Invitation letters sent to farmers by post.

Forespørsel om deltakelse i forskningsprosjektet

'Potensiale for anvendelse av biokull i gartnerinæringen på Finnøy og Rennesøy'

Bakgrunn og formål

Formålet med studien er å kartlegge interessen og potensialet for bruk og evt. produksjon av biokull på Rennesøy og Finnøy.

Prosjektet er en master-studie i Agroøkologi (læren om bærekraftige mat-og gårdssamfunn) ved Norges Miljø- og Biovitenskapelige Universitet (NMBU). Prosjektet gjøres i samarbeid med IVAR IKS.

Deltakere er valgt til studiet på bakgrunn av deres tilknytning til gartnerinæringen på Finnøy og Rennesøy, deres tilknytning til fagmiljøet for biokull, eller deres tilknytning til IVAR IKS.

Hva innebærer deltakelse i studien?

Studien innebærer datainnsamling gjennom intervjuer/samtaler på mail, telefon og ansikt til ansikt av varierende lengde (avhengig av interessen til den enkelte deltaker).
Dette vil være enkeltintervjuer og evt. gruppesamtaler og diskusjoner.

Informasjon om deltakere (yrke, nettverk ol.) hentes fra internett og eventuelt andre nøkkelpersoner i nettverket (andre informanter).

Informasjonen vil bli lagret skriftlig i form av notater for hånd og på PC.

Spørsmålene vil omhandle:
- Deltagernes tidligere kjennskap til biokull
- Deltakernes interesse for å lære mer om og og å evt teste ut, anvende og produsere biokull
- Deltakernes interesse for å evt arrangere/bli med på en studietur/informasjonstur/workshop til pyrolyseanlegget i Sandnes

Hva skjer med informasjonen om deg?

Alle personopplysninger vil bli behandlet konfidensielt. Informasjonen vil være tilgjengelig for student Eva Karachristianidis og hennes veiledere, samt studiegruppen dersom det arrangeres en workshop.

Deltakerne vil kunne gjenkjennes i publikasjonen, dersom den enkelte samtykker til dette. Det skal f.eks. Lages et nettverkskart hvor nøkkelbedrifter vil kunne gjenkjennes.

Prosjektet skal etter planen avsluttes 30 November 2018.
Datamaterialet vil deretter lagres digitalt på ubestem tid hos masterstudenten, i alle fall til innlevering og forsvar av masteroppgaven er gjennomført. Noe av informasjonen vil også være tilgjengelig i selve rapporten som skal skrives, og som vil offentliggjøres til NMBU og IVAR, samt andre interesserte.

Frivillig deltakelse

Det er frivillig å delta i studien, og du kan når som helst trekke ditt samtykke uten å oppgi noen grunn. Dersom du trekker deg, vil alle opplysninger om deg bli anonymisert.

Dersom du ønsker å delta eller har spørsmål til studien, ta kontakt med masterstudent Eva Karachristianidis, telefon: 48021873 eller hennes veileder hos IVAR IKS, Rudolf Meissner, mail: rudolf.meissner@ivar.no.

Studien er meldt til Personvernombudet for forskning, NSD - Norsk senter for forskningsdata AS.

Samtykke til deltakelse i studien

(Sett kryss for det som gjelder deg)

☐ Jeg har mottatt informasjon om studien, og er villig til å delta

☐ Jeg samtykker til at personopplysninger kan publiseres og lagres etter prosjektslutt

☐ Jeg ønsker å anonymiseres i rapporten

(Signert av prosjektdeltaker, dato)

Navn på mottaker
Org.nr.:
Firmanavn
Gateadresse
Poststed, postnummer

Kjære, Navn på mottaker:

Mitt navn er Eva Karachristianidis, og jeg skriver for tiden en masteroppgave ved NMBU (Norges miljø- og biovitenskapelige universitet) som kan være av interesse for deg. Den handler om **alternative bærekraftige løsninger for veksthusnæringen**.

I oppgaven vil jeg fokusere på Finnøy og Rennesøy for å se om det der er grunnlag og interesse for å produsere og benytte **biokull**.

Biokull er karbonisert biomasse, ganske likt grillkull, og produksjonen av dette i en såkalt pyrolyseovn avgir energi som kan benyttes til f.eks. oppvarming av veksthus.

Jeg har lagt ved et lite informasjonsskriv om biokull og dets relevans for dere som driver veksthus dersom du vil lese mer om det.

Det interkommunale selskapet **IVAR IKS** støtter aktivt opp om prosjektet. Prosjektet har også vekket interesse hos landbruksmyndighetene i Finnøy og Rennesøy kommuner. Disse holdes orienterte om prosjektets fremgang.

Tittelen på prosjektet mitt er: **«Potensiale for anvendelse av biokull i gartnerinæringen på Finnøy og Rennesøy – en mulighetsstudie»**.

Kort fortalt ønsker jeg å lære mer om hvilke synspunkter og erfaringer dere i veksthusnæringen har, og hvordan disse synspunktene og erfaringene kan begrense og motivere utviklingen av biokull som en alternativ løsning for næringen.

Jeg håper at du synes at dette høres spennende ut, og at du kan avse litt tid til å treffe meg for et intervju i løpet av august, september eller oktober. Intervjuet vil vare rundt 45 minutter.

Dersom du har spørsmål eller kommentarer er det bare å kontakte meg. Jeg kan nås på telefon: **48021873**, e-post: eva.karen.k@gmail.com, eller post:**Eva Karachristianidis, C/O IVAR IKS ved Rudolf Meissner,Postboks 8134, 4069 Stavanger.**

Gi meg tilbakemelding innen 31. august både dersom du ønsker å delta, og dersom du ikke ønsker å delta.

Jeg ser fram til å høre fra deg!

Vennlig hilsen

Eva Karachristianidis

Appendix 4: Interview guide.

Mulighetsstudie for Biokull – Fokus: Finnøy og Rennesøy

Intervjuguide

Dato:

Navn:

Rolle:

Formålet med studien:
Å avdekke mulighetene for og interessen rundt bruk og produksjon av biokull på Rennesøy og Finnøy.

NB! Intervjuet gjøres sammen med en kort presentasjon av prosjektet og bakgrunnen for det.

Spørsmål:

- Hvilken **kjennskap** har deltakeren til biokull fra før av?

- Er deltakeren interessert I å **lære** mer om biokull?

- Er deltakeren interessert I å **prøve** ut biokull I sin virksomhet?

- Er deltakeren interessert I å **produsere** biokull selv?

- Er deltakeren interessert I å **være med** i en workshop/mulighetsgruppe for biokull I regionen?

- Har deltakeren andre tanker eller ideer rundt prosjektet?

B I O K U L L

HVA ER BIOKULL?

BIOKULL (*biochar*) er et veldig porøst karbon-materiale laget av biomasse (organisk materiale) gjennom en **PYROLYSE**-prosess. I pyrolyse-prosessen varmes biomassen opp til 400-800 °C med liten tilgang på oksygen. På denne måten bevares og stabiliseres strukturene i biomassen. Disse strukturene er motstandsdyktige mot nedbryting.

Biokull egner seg for b.la. karbonlagring i jord og som et ledd i jordforbedring. Biokullet må 'lades opp', 'aktiveres' eller 'mettes' med væske før bruk, og vann og næringsstoffer huses i porene for sakte frigjøring til omgivelsene.

Pyrolyse-prosessen frigjør også bioenergi, som kan brukes til f.eks. oppvarmingsformål.

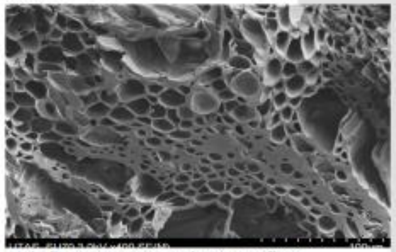
Det å lage og bruke biokull kan være en enkel måte å håndtere forurensing og å høste energi, ved hjelp av biomasse som ellers kan sees på som avfall.

UTVIKLING OG HISTORIE

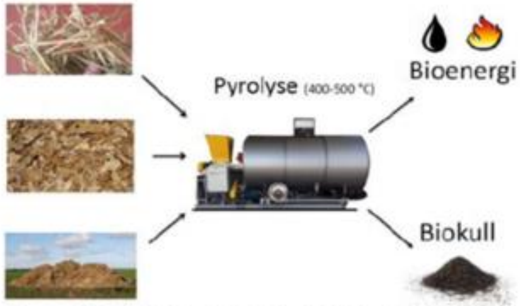
Biokull er en eldgammel teknikk. En finner rester etter såkalt TERRA PRETA, eller SVARTJORD, flere steder i verden. Mest kjent i Amasonas.

Dette er menneskeskapte kullrester i jord, som 500 år etter tilsetning fremdeles er mer fruktbar enn jorda rundt. Man tror at kull-rik *terra preta*-jord bevisst ble skapt av lokalbefolkningene for å dyrke mat til sine store befolkninger.

Disse oppdagelsene har ført til stort forskningsfokus på biokull. Funnene indikerer potensiale for langvarig jordforbedring og karbonlagring – stabil lagring av karbon i jorda i hundrevis av år.



Biokulls porøse, svampaktige overflate.



Figur 1 Verdikjeden for biokull. Kilde: O'Toole 2017

Pyrolyse-prosessen.

AMASONSK SVARTJORD (*TERRA PRETA*)

Til venstre: en næringsfattig *oxisol*. Til høyre: *Oxisol* omdannet til *terra preta*. Bilde: Bruno Glaser

BRUKSOMRÅDER FOR BIOKULL

Mulige direkte bruksområder for biokull kan være:

- Stabil karbonfangst- og lagring i jord
- Produksjon av gass og varme
- Fangst av avrenning fra jorder
- Forbedret dyrehelse ved tilsetning i for og strø
- Vannfiltrering

Man kan også kombinere biokull og:

- Avløpsslam eller gjødsel fra husdyr- og fiskeindust dette gir:
  - forbedrede gjødselsmidler
  - luktredusering av slammet/gjødselen
- Kompost - dette bygger opp innholdet av v mineraler, og mikrobiologisk aktivitet
- Papir/papp for å lage komposterbar emballasje
- Bygningsmaterialer så som betong, for å lage materialer for lyd- og varmeisolering, og flammehemming.

****

Dette informasjonsskrivet deles et ledd i masterprosjektet «Pote for anvendelse av biokull i gartnerinæringen i Finnøy og Rennesøy – en mulighetsstudie

Har du spørsmål eller komment eller er du knyttet til gartnerinæ Finnøy eller Rennesøy og ønsker i prosjektet i form av et intervju, kontakt med:

Eva Karachristianidis
(masterstudent ved NMBU)
Mail: eva.karen.k@gmail.com
Tlf.: 48021873

****

MATERIALER SOM KAN BRUKES TIL Å LAGE BIO

Mange typer bio-avfall så som treflis, avkapp, grener, bladverk, halm, fast husdyrgjødsel, tø gress kan omvandles til biokull. Det finnes m muligheter for å benytte materialer (biom som er til overs fra land-, fiske- og skogsbruk, fra opprydding langs veier, i parker og i hager.

Forskjellige typer biomasse har forskjellige t egenskaper, og vil skape forskjellige typer bio Det forskes for tiden på hvilke biomasser so optimale for forskjellige bruk.

For bruk i landbruk er det viktig at material rent.

Det finnes også sertifiseringsordninger for bi som et ledd i å sikre kvaliteten på biokullet.

ET ALTERNATIV FOR VEKSTHUSNÆRINGEN

Produksjon og bruk av biokull kan være et alternativ for veksthusnæringen – både som energi- og varmekilde og som en del av vekstsubstrat og emballasje.

I det internasjonale EU-prosjektet HortiBlueC forskes det blant annet på biokull og bruk i forbindelse med f.eks tomatproduksjon. Resultatene av prosjektet ventes klare i 2021. Les mer her: https://www.interreg2seas.eu/en/Horti-blueC

Veksthusene kan stå for mulige **INNPUTT** til biokullproduksjonen. Eksempler kan være:

- Stengler og blader
- Syke og skadede planter
- Infiserte planter
- Oppbrukte (organiske) vekstmedier
- Overskuddsproduksjon

Andre lokale innputt kan være:

- Opprydding og rester fra juletre-produksjon
- Rester og avfall fra trevareproduksjon
- Fiskeslam fra akvakultur (tørket)
- Innsamlet hage-, park-, veiryddings- og skogryddings- avfall
- Sikterester fra treflisproduksjon

Det er mulig å kombinere biokullproduksjon med veksthusdrift. Man kan f.eks gjøre direkte bruk av varmen og energien fra pyrolyseanleggene og med det redusere eller eliminere behovet for andre energikilder (så som naturgass). Det kan også bli mulig å benytte biokullet og CO_2-en fra anlegget direkte i veksthusproduksjonen.

Det finnes forskjellige typer biokull-anlegg til forskjellige typer behov, og man kan justere mengden biokull og energi man får ut av dem om ønskelig.

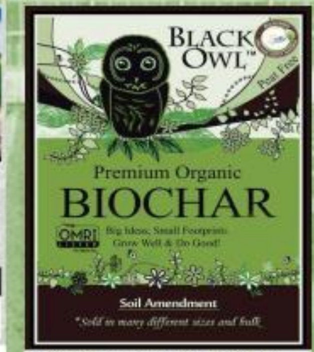
MULIGE MARKEDER FOR BIOKULL

Dersom man har et pyrolyse-anlegg i tilknytting til veksthusproduksjon, men ikke gjør bruk av biokullet direkte i veksthuset kan det finnes andre markeder som kan gjøre nytte av biokullet. Eksempler på slike markeder kan være:

- Husdyr-, kjæledyr-, fjærkre og akvakulturindustrien som:
  - Fôrtilsetning,
  - Strø
  - Slamtilsetning
  - Jordforbedringsmiddel
- Biogassproduksjon som:
  - Katalysator for økt biogassutbytte
- Hagebruk, park- og veivesen:
  - Tilsetning i kompost
  - Jordforbedring
  - Filtrerings- og avrenningsordninger

Bruksmuligheter for biokull forskes det også på, blant annet i NIBIOS prosjekter CarboFertil, Karbonvekst, INTENSE og CAPTURE+. Resultatene av disse prosjektene forventes klare i løpet av 2021. Oplandske Bioenergi AS holder på med forskning på biokull som fôrtilsetning til melkekyr i samarbeid med TINE SA.

CharLine GmbH, Østerrike: Fôrtilsetning for fjærkre. Pris ca. 15EUR per kg (15 000 EUR/tonn)



Biochar Supreme, USA: Black Owl Biokull-produkter, OMRI-sertifisert.

ER BIOKULL LØNNSOMT?

Det er for tidlig å si sikkert om det vil lønne seg for veksthusnæringen å satse på biokull. Basert på beregninger gjort i forbindelse med pyrolyseanlegget Sandnes kommune har anskaffet seg, er regnestykket som følger:

Anlegget produserer **100 kW/t**, og har **6000 driftstimer i året**. Flis fra hage- og parkavfall leveres gratis til anlegget. Kostnadene (uten investeringsstøtte*) ved en 50-50% fordeling av kostnadene på henholdsvis energi og biokull er:

0,41 kr/kWh for varmeenergien
3255 kr/tonn biokull produsert

For spørsmål rundt disse tallene, ta gjerne kontakt med Sandnes kommune, eller Rudolf Meissner hos IVAR IKS, som står for beregningene.

I andre deler av Europa ligger salgsprisene for biokull rundt:

- 600 EUR/tonn rent biokull
- 1000 EUR/tonn fôr-kull
- 1500 EUR/tonn for aktivkull (biokull kan foredles)

Det er også mulig at det i fremtiden vil komme støtte-ordninger for karbon-lagring som vil påvirke regnestykket ytterligere i positiv retning.

*Innovasjon Norge kan tilby investeringsstøtte på inntil 45% til bygging av biokull-anlegg (pyrolyseanlegg). Les mer på Innovasjon Norge sine nettsider og i artikkelen 'Når kan biokull bli vanlig i norsk landbruk?' på nibio.no

EBC: Europeisk sertifiseringsordning for biokull

IBI, International Biochar Initiative: Internasjonal organisasjon og nettverk for biokull.

Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

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