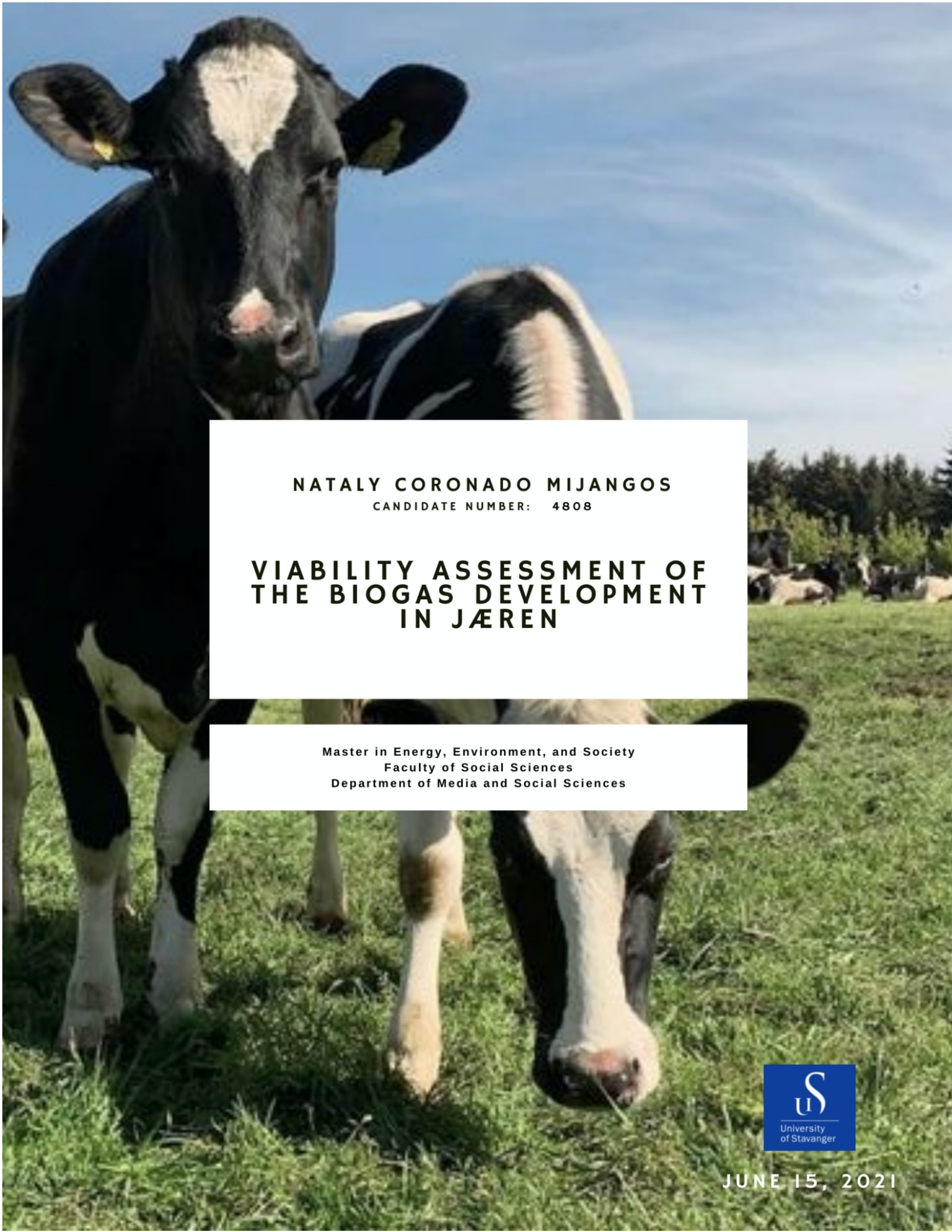

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VIABILITY ASSESSMENT OF THE BIOGAS DEVELOPMENT IN JÆREN

Master in Energy, Environment, and Society
Faculty of Social Sciences
Department of Media and Social Sciences

University of Stavanger

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Abstract

The main purpose of this thesis is to explore the existing will to accelerate biogas production in South Jæren (Sør-Jæren), more precisely in the communities of Vigrestad, Varhaug, and Nærbø. It centers on analyzing the agricultural industry and incentives from government entities to promote biogas development in the area. It has also analyzed the current factors in the region that prevent the transition from taking place, such as expenses generated by transport, agricultural regulations, and, most importantly, the participation of farmers in such decision-making.

The Norwegian authorities have envisioned biogas as a potential catalyst for the region's economy, as well as being an agent in Norway's greener transition, helping farmers manage waste, creating green energy, and reducing local pollution. There exist two impactful alliances from well-known companies, Felleskjøpet, Lyse, and Ivar being one, and Tine, Nortura, Ivar, Air Liquide, and Greve Biogas being the second. They have shown interest in investing in the development of biogas plants in South Jæren. In this sense, the study aims to examine the changes. Implementing the Multi-level Perspective theory has helped identify the actors and the interplay of such within the transition. This thesis evaluates the current transition management, which aims to promote biogas as a key factor in mitigating methane emissions caused by livestock manure, as well as a possible route of additional economic development for farmers. The investigation was implemented as a research strategy of interviews with an inductive and abductive approach conducted with local farmers to examine the current landscape in the area.

Based on this data collection, this paper concludes that in order to obtain satisfactory development, it is crucial to address every actor and aspect in the chain by implementing a competent transition management process. Furthermore, it is necessary for the interplay of every actor not to repress the development of the technology.

Det lukter penger!

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List of Abbreviations:

AD:	Anaerobic Digestion
BOD:	Biochemical oxygen demand
CH_3COOH:	Acetic Acid
CH_4	Methane
CO:	Carbon monoxide
CO_2:	Carbon Dioxide
COD:	Chemical Oxygen demand
Eq.:	Equivalents
EU:	European Union
GDE:	Manure unit
GHG:	Greenhouse gas
GW:	Gigawatt
GWh:	Gigawatt per hour
H-O:	Hydroxide
H_2:	Hydrogen Sulfide
H_2S:	Hydrogen Sulfide
HVO:	hydrotreated vegetable oil
Kg:	Kilogram
LNG:	Liquefied natural gas
M3:	Cubic meter
MLP:	Multi-level Perspective
N_2:	Nitrogen
N_2O-N:	Nitrous Oxide

NB2020:	Nasjonalbudsjettet for 2020 (Norwegian National Budget for 2020)
NH_3:	Ammonia
NORCE:	Norwegian Research Center
NO_x:	Nitric oxide
O_2:	Oxygen

Acknowledgments

This thesis represents the culmination of my studies in the Masters of Energy, Environment, and Society. Although I have been aware since my early years of the harms that climate change has caused throughout the years in different parts of the hemisphere, this program gave me a deeper perspective on the different scenarios this problem represents worldwide. Coming from a developing country, the knowledge earned throughout these two years has brought up light to crucial factors that must be considered when discussing a greener change, not only in Europe but most importantly, the rest of the world.

I would like to thank the entire staff of Stavanger University for encouraging us to pursue our dreams of change. The shared knowledge, the discussions, and the energy solutions provided have inspired me to be more analytical.

To my supervisor, knowing my limitations and still having faith in what I could create out of it in this research.

To my friends and peers who were always finding the time to discuss important aspects of this research. Thank you, John and Juan.

Most importantly, I would like to thank my husband for his constant support; without his motivation and guidance, this might have been a difficult task to achieve on my own, to my son, whose existence has given me the will to seek solutions that will allow him to have a better world in every context possible. Your existence fuels my stamina.

1. Introduction

With the signing of The Paris Agreement in April 2016, Norway agreed to reduce its greenhouse gas emissions to fight climate change. "The agreement aims to increase the ability of countries to deal with the impacts of climate change, and at making finance flows consistent with low Greenhouse gas (GHG) emissions and climate-resilient pathways" (UNFCCC, 2019). This also has implications for specific regions in Norway like Jæren. According to the Norwegian Research Center (NORCE) report, Rogaland has 10% of Norway's population and no less than 20% of its domestic animals.

One of the main problems identified in NORCE's report is that due to an insufficient area to spread all the manure, as well as a phosphorus surplus problem that leads to runoff, some farmers may be forced to have to reduce their animal stocks by as much as 25-50% (NORCE, 2019). This is where using surplus manure in biogas production becomes a promising potential solution by allowing farmers to utilize the excess in energy production as a potential source of additional income instead of being forced to reduce their animals to limit manure production. Already Norwegian farmers are feeling under pressure, exemplified by the recent large-scale protests shown on May 7th, 2021, all over Norway, demanding better conditions and financial support (NRK, 2021), and anything that tips the scale in one direction or the other can be important for the future regional and national agricultural development. For Rogaland to achieve the climate goals and maintain high employment levels, this is one of the more promising implementations that can help the South Jæren.

Existing infrastructure like gas pipelines in place in Jæren will also help facilitate biogas production as a viable strategy for the region since it can help reduce costs, both from heavy vehicle transportation and energy infrastructure convergence. However, many challenges still exist, which complicates the transit and energy biogas implementation in Jæren. Whether farmers are willing to make the necessary investments in equipment and practices remains an important question to explore and research.

This thesis has focused on reviewing Jæren's potential to increase its biogas production and manure basics from anaerobic digestion technology. What are the challenges that Jæren needs to overcome to achieve a sustained and long-lasting transition, and where are the possibilities? This research will look at the different scenarios of how biogas in Jæren has implemented means for GHG emissions and the impacts of the different scenarios on the economics for the farmers. Finally, it will look at what policies and public interventions are being considered to be helpful for this transition.

After conducting the literature review based on biogas technology and its process and the potential scenarios, policy, and potential support in the South Jæren area, this thesis will also address the key actors involved in the process in section 2. This thesis has chosen to investigate the research questions and the subjects that have incentivized the problem statement in section 3. The theory implemented as the foundation of this research; Multi-level perspective, and Transition Management will be depicted in section 4. The research strategy, focused on the Inductive and Abductive inference method, will be presented in section 5. The qualitative and quantitative research methods used for this research are explained in section 6. Data collection and reduction are described in section 7. Section 8 will expound on what the limitations of the study are. Results gathered based on interviews are displayed in section 9, followed by the discussion in section 10. The conclusion of this research lies in section 11 and recommendations for future studies in section 12.

1.1 Jæren´s background

The name "Jæren" has both a geographical and an administrative meaning. Administratively, only the municipalities Klepp, Hå, Sola, and Time are considered part of Jæren, while geographically, Sandnes, Stavanger, and Randaberg are also considered to be part of it, with some exceptions in the eastern parts of Sandnes (Thorsnæs, 2019). Although all the municipalities of Jæren only have 0,5% of Norway's land area, they have 4,7% of the agricultural land area. Livestock is significant for Jæren, as witnessed by the fact that although Jæren only has 0,9% of the total corn area, it has as much as 22,4% of the country's breeding pigs, 16,7% of the country's hens and 10,3% of the country's cattle (Thorsnæs, 2019). Jæren also has several public institutions working with agriculture.

Much of the industries in Jæren are connected to agriculture, and these include dairy producers, agriculture equipment, and machinery producers. That said, the most crucial industry in Jæren, at least in regards to the number of people employed, is mining, which includes oil extraction and related services, which employs 65% of the people employed in industry (Thorsnæs, 2019).

A few things stand out regarding biogas production. First, much of the agriculture in the region is related to livestock, which is essential for the potential of biogas production that Jæren might be capable of achieving. As explained in the introduction, the pressing issue of enough area for spreading manure further acts as an impetus to explore the possibilities for biogas production in Jæren. Another point worth noting is the historical experience with the spinoff industries that come from agriculture in the region, as local historian, Jøssang makes clear in conclusion to *The Industrial Adventure in Jæren 1800-2000*: "agriculture, operation of land and livestock, and industry (...) have been typical for capitalism in Jæren. Until recent times the economy of Jæren has had a strong agroindustrial influence" (Jøssang, 2004, p.323-324). This could signal an experience with exploring and making use of synergies between various sectors that would be important if biogas production ever became a large-scale enterprise in Jæren.

2. Literature review

Biogas technology implementation can be beneficial for South Jæren. It can provide a new source of income from electricity production and consumption aspects for the area itself, not to mention that it can aid in achieving the current national GHG emission reduction target plan for 2030. However, the viability of biogas production in the region is and can be impacted by different actors. Identifying and understanding them will help facilitate a more profound understanding of whether biogas can be a technology worth implementing or not. This section analyzes important actors and policies, and regulations in the agriculture industry, which are among the topics to be discerned.

2.1 State of biogas in Europe

The European Union (EU) is a global leader when it comes to bio-power capacity and generation. In 2015 the capacity at operation was 30GW, almost twice the amount in the United States (US) which was at 16,7GW (Scarlat et al., 2018). China and Brazil respectively stand at 10.3GW and 9.7GW as of 2015. The EU is also the world leader in biogas electricity production. Globally this amounts to 15GW of installed capacity as of 2015, and as much as 10.4GW of the installed capacity is in Europe (Scarlat et al., 2018).

Favorable policies put forward in the different EU countries have been a fundamental reason for the fast-moving speed and the dominant position of bioenergy and, more specifically, biogas development in Europe. Most of the growth came from anaerobic digestion and sewage gas from wastewater treatment, although this last did not contribute to anaerobic digestion. Most biogas in the EU is used for electricity generation, this can either be purely electricity generation, or it can be implemented in combined heat and power plants that are more efficient, as they take into use the waste heat. Improving the economics of biogas production also matters in terms of using combined heat and power. In Europe, Germany is a clear leader in biogas production, with as much as 50% of total biogas production. Other notable countries are France, Italy, and the United Kingdom (Scarlat et al., 2018)

Several factors, including poor economics of traditional biogas, technological improvement and opportunities arising for the transport sector, have led to a shift in trends from using biogas directly for electricity and energy generation, to upgrading it to biomethane. This opens up new opportunities for biomethane usage in natural gas-powered vehicles and is injected directly into the natural gas grid. It acts as a substitute for traditional natural gas, to which biomethane has enormous similar properties. Grid injection also helps with the poor conventional biogas economics mentioned earlier, as it allows it to be stored at a lower cost.

Although biogas' role in bioenergy production is still relatively small, it has been growing. In 2005 it was a share of 2,7 percent, while in 2015, that share had increased to 7,8 percent (Scarlat et al., 2018).

2.2 State of biogas in Norway

Norway's energy consumption per capita is similar to the rest of its Scandinavian neighbors but relatively more significant than other countries; this mainly hinges on its power-intensive industry and heating (Landbruks og Matdepartement, 2009, pp. 113).

The Norwegian government St.meld. nr. 39 report *The Climate Challenges - Agriculture part of the Solution* (Klimautfordringene – landbruket en del av løsningen) published in 2009, dwelled on the possible productive effect animal manure-based biogas plants could have in regards to GHG emission curtailment. It also aimed to increase bioenergy development nationally up to 14TWh by 2020. To do so, it was stated based on the Norwegian Pollution Control Authority research that "30 percent of all livestock manure in Norway for biogas production together with 600,000 tonnes of food waste, GHG emissions will be reduced by 0.5 million tonnes of CO_2 equivalents… by 2020 " (Klimautfordringene, 2009, pp.100).

Such lofty ambitions were not met, since as of today, only approximately 70,000 tonnes of livestock manure resources are being used for biogas production. This is only 1% of total manure resources, a number that falls far short of the 30% goal (Landbruksdirektoratet & Fylkesmannen i Vestfold og Telemark, 2020).

In 2010, to estimate measures and instruments that can and will contribute to achieving Norway's national target regarding GHG emission development, a report was put in place by Norwegian professional entities (Miljødirektoratet, Statens vegvesen, Kystverket, Landbruksdirektoratet, Norgesvassdrags, Energidirektorat, and Enova) Klimakur 2020. Klimakur 2020 was prepared to show the potential for reducing GHG emissions in the non-quota sector and measures to increase uptake and reduce emissions from forests and other land use types (Miljødirektoratet, 2019). The report demonstrated that the estimated cost of production and distribution from biogas production was higher than previously expected from St.meld. nr. 39 had anticipated. Hence, biogas production development regarding livestock manure remained limited; the farmers do not have to pay for their emissions; therefore, it is not profitable to reduce them.

Furthermore, the cost estimated for 30 % of livestock manure in co-treatment plants came to about NOK 1200-1300 per tonne of CO_2 equivalents. This is prohibitively high if compared with the already record-breaking price of carbon in the EU emissions trading scheme, which reached 56 EUR on May 17th (Meredith, 2021). However, the report also reckons how prices may vary based on livestock density, transport distances, and so forth in individual plants: “For example, two large biogas plants in Rogaland will be able to reduce emissions by 54,000 tonnes at the cost of NOK 700 per tonne of CO_2 equivalents" (Klima og miljødepartement, 2012). NOK 700 is much closer to the current price of CO_2 equivalents in the EU, and if the price keeps rising, we may end up in a situation where biogas schemes in Jæren make financial sense.

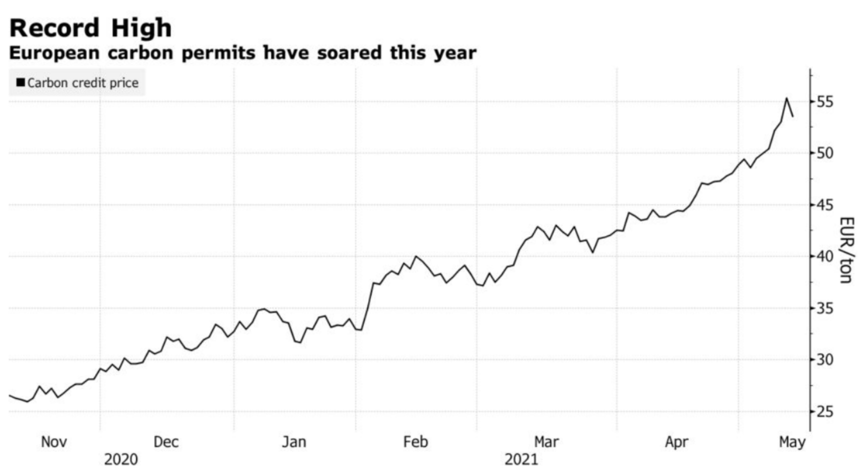

Figure 1: Carbon credit price (Krukowska, 2021).

Seven identified farms treat livestock manure in conjunction with food waste or treat livestock manure separately in Norway. The different plants are: Greve biogas plant in Vestfold, which co-process fertilizers with other substrates; Tomb and Holum's farms allocated in Østfold and Nitedal respectively, which treat manure and food waste and Hugaas, Porsgrunn, Klepp, and Tingvoll farms that treat manure separately. (NIBIO, 2017). One of these plants has significant impacts within the biogas field: The Greve biogas treatment plant, *Den Magiske Fabrikken,* located in Tønsberg. Den Magiske Fabrikken is the only plant in Norway to accept livestock manure on a larger scale, leading to increasingly positive results. The number of enterprises that had joined this process has increased notability since the plant's beginnings in 2015, where 18 companies represented approximately 15,000 tonnes of manure delivered. As of 2018, its thirty member company quadrupled the amount of manure to approximately 62,000 tonnes (Landbruskdirektorate, 2020). Den Magiske Fabrikken's successful results have incentivized Greve Biogass to expand towards Rogaland, where private companies such as the dairy factory Tine, the agricultural cooperative Nortura and the French gas company Air Liquide are set to join forces. This will be further explained in the next section, *2.5 Actors at play.*

2.3 State of Biogas in Rogaland

Rogaland is aware of the potential bioenergy that it can provide to the region. Furthermore, it aims to become at the forefront of the innovative bioeconomy. Rogaland knows that it has the resources for such development; for instance, its location entails an advantageous position to develop biogas and scale-up fermentation processes (Rogaland fylkeskommune). Biogas can aid in facilitating new jobs while producing greener and more sustainable energy. Rogaland fylkeskommune, a governmental entity responsible for safeguarding the region's best interest, has developed a strategy report for 2018 to 2030 (Strategi for bioøkonomi i Rogaland 2018 - 2030); it analyses the strengths that Rogaland can provide for lowering emissions schemes by incentivizing bioeconomy in Rogaland. The strategy makes such propositions based on the analysis of business policy, knowledge policy, and research policy:
"The strategy is a regional policy management document in the prioritization and distribution of economic instruments, and for regional research and education strategies" (Rogaland Fylkeskommune, 2018, pp.1).

As the report describes, the interest in launching a bioeconomy in Rogaland is due to the decline of the petroleum industry, which can be a good opportunity for the region to invest in bioenergy production; one that will create employment and value in Rogaland. In addition, the location of the area will add value regarding development and scale-up fermentation. However, it is implicit how such adjustments will impact the cost, especially replacing fossil gas to heat buildings with new technology. Among the barriers lie the increased operating cost and investment cost (Klimaskur 2030, 2020). "Switching to biogas has a higher energy cost than with fossil gas, but the consumer then has no investment costs to install a new solution as the same equipment can be used for fossil gas as for upgraded biogas " (Klimakur 2030, 2020). A company working on such an approach is Lyse Neo i Rogaland, where the company is already mixing a share of biogas in its natural gas network, which they sell according to the mass balance principle (Klimakur 2030, pp.289). The Lyse gas center Skangass is located on the sea bay Risavika, part of Sola municipality in Rogaland. It has recently transformed its natural gas into a Biosentrum, making Rogaland more capable of converting residual raw material into different products (Rogaland Fylkeskommune, 2020, pp.8). Keeping in mind that the oil industry in Rogaland is a well-developed area that carries significant knowledge regarding technological developments, it will entail that enormous opportunities regarding technology transfer to the biotechnology sector exist and are possible. This solution is a genuine opportunity due to the large industry that the region possesses, where significant emissions are being emitted; transforming this energy loss into green energy could also reinforce the need for bioeconomy to take place (Rogaland Fylkeskommune, 2020. pp. 9).

Such a perspective has been evaluated by the Norwegian Institute of Bioeconomy Research (NIBIO). NIBIO is in charge of researching food production, forestry, and other bio-based industries with the aim of providing a more safe, secure, and sustainable resource management (NIBIO, 2020). NIBIOs report: *Klimatiltak i jordbruk og matsektoren: kostnadsanalyse av fire tiltak, 2017,* explains that this proposition can be a reality if the implementation of livestock manure for biogas production is increased from the current 1% to 50% by the year 2050. The emission reduction is estimated to correspond to 151,000 tonnes of CO_2 per year, having a socio-economic cost of NOK368 per tonne of CO_2 (NIBIO, 2017).

Furthermore, the report, section *Production of biogas from livestock manure,* expounds on how the current situation of animal manure is not being carried to biogas production. Instead, it is being spread directly on the soil without treatment, leading to methane ammonia and nitrous oxide emissions (NIBIO, 2020). "Nitrogen lost through evaporation to air in the form of ammonia (NH_3) and nitric oxide (NO_x) can lead to nitrous oxide emissions after precipitation. An emission factor of 0.01kg N_2O-N/kg N lost to air (1%) is calculated. Nitrogen lost by runoff can also, in turn, lead to emissions of nitrous oxide" (NIBIO, 2020).

NIBIO also expounds on the importance of reducing ammonia loss from livestock manure during spreading, especially during Autumn, in order to reduce the risk of run-offs (NIBIO, 2020). Another essential factor to be considered is the amount of phosphorus that livestock manure contains. In Norway, manure is the main secondary source of phosphorus (11,400 tonnes), followed by fish sludge and sewage sludge. Currently, the country holds more "plant-available phosphorus" in the manure than what the plants in the fields need. This could be another possible industry that can be developed, where "Norway's internal phosphorus can provide a basis for exporting recycled phosphorus as fertilizer abroad" (COWI, 2020, pp.12). Jæren is not the exception regarding this matter. This could be beneficial for Jæren's bioeconomy. However, the production of such involves high technological investment, one that Jæren lacks at the moment, leading to a high price of phosphorus compared to other mineral fertilizers (COWI, 2020). Furthermore, the raw manure spraying method in Rogaland is still handled the same way, which entails that the current capacity and treatment will continue if investments are not being sought.

Rogaland represents 20% of the livestock manure of Norway. Miljødirektoratet assumes that 30% of the manure in Rogaland will be co-treated with 40,000 tonnes of wet organic waste. It is expected when the two biogas plants are built in Jæren (1.Ivar, Felleskjøpet, and Lyse. 2.Air Liquide, Nortura, and Greve Biogass, further explained in section *"2.6 Actors at play"*), they jointly will represent a gas volume of almost 80GWh.

As explained above, several reports have been published on the environmental impact of livestock manure when not appropriately treated. More so, such treatment can be handled from biogas production while providing employment, a waste management solution, energy, and, most importantly, a more sustainable, greener bioeconomy.

2.4. Regarding land regulations and manure

This thesis has discussed the current state of biogas both internationally and in Norway. In this regard, the importance of farm animal manure is twofold; on one hand, it is the possible means of production of biogas; on the other, farmers have strict limits on how much manure they are allowed to spray in their fields, as current laws stipulate. Therefore, this last factor needs to be examined.

Regulations were established by the ministry of agriculture and the ministry of the environment in 2002, according to the law 23 stipulated in 1995, Soil Law (Jordlova) from paragraphs § 3 and § 11 and from 1981 law, Pollution (Forurensningsloven), paragraphs §9 and §81 (Lovdata, 2021).

The law expounds on the importance of regulations that must be undertaken regarding livestock manure as a prevention method of possible air, watercourses, groundwater, fjords, and sea areas pollution that might be endangered by mistreated practices in agriculture. Furthermore, "it is also a goal to reduce the disadvantages of odor and particle dispersal as a result of disposing of livestock manure rebuilt-up areas" (Landbruksdepartementet, 2002 § 1). Therefore, within the law, it is also considered that such regulations also apply to the collection, storage, and spreading of livestock manure. Notably, the law also stipulates that manure must only be spread on approved spreading areas; areas that constitute a minimum of 4 decares (1 decare is equal to 1000 square meters) of fully or surface cultivated soil per manure unit (GDE) and must not exceed 17kg of total nitrogen per decare.

"A manure unit corresponds to a secreted amount of phosphorus of about 14kg in livestock manure" (Landbruksdepartementet, 2002 § 5). The period for the spread of manure is set to occur from the beginning of Spring to the first of September, could also be prolonged until

October 31, but under any circumstances, regardless of the date, it is prohibited to spread manure on snow-covered or frozen ground.
Section 8 of the law addresses the storage capacity the farm must have for manure and fertilizer, determining that it must hold at least eight months capacity of manure; in case of any expansion, improvement, or new construction on the storage, it must be checked and approved by the municipality. Furthermore, asserting that the storage is tight against leaks and under no reason must the storage be located to watercourses, wells, or other water supply facilities that might represent a risk of pollution. Thus, it is evident that the law has formulated a thorough method to counter any possible forms of contamination from manure, especially in regards to water and air pollution.

Furthermore, based on such clauses, an annual agricultural settlement (Jordbruksoppgjøret), where negotiations between the Norwegian government and the farmers take place concerning financial support from the state to the farmers. The agricultural settlement stipulates target prices (the price farmers can charge for several key goods; grain, milk, pork, meat, fruits, and vegetables) and production subsidies, among other subjects, in order to ensure farmers' income (Molnes, 2021). This year has been in turmoil over the agricultural settlement respecting the amount demanded by the Norwegian farmers' unions, which is to be over NOK 2.1 billion, and a demand for a package outside the settlement, valued at NOK 450 million. The package would secure the transition from stall barns to loose housing barns, which will entail "reducing the income gap, increase the Norwegian share of feed and food, strengthen welfare schemes and facilitate climate-friendly and sustainable food production, according to agricultural requirements" (Molnes, 2021). The Norwegian government submitted a counteroffer of NOK 962 million and stated that this should create an income growth of 4.5%. Such discontent from the farmers was visible around the streets of Norway in the following days; since the parties have not reached an agreement, the responsibility of determining the agricultural agreement will fall on the parliament to decide. "It is also worth mentioning that farmers have a lot of debt. In 2019 the average debt was NOK 2.2 million (…). The debt ratio has risen significantly in recent decades. According to the financial group Landkreditt, the average debt was NOK 579,000 in 1999" (Molnes, 2021).

A significant possible development is new, stricter manure use requirements. The proposal submitted by the Norwegian Directorate of Agriculture (Landbruksdirektoratet) addressed the modifications to be made to the required amount of manure to be spread; a maximum limit to 3kg of phosphorus per decare that was reduced to 2,5kg and the Norwegian Environment Agency (Miljødirektoratet) recommended a 2,1kg phosphorus per decare limit. Rogaland is the county to suffer the most from the excess net of manure if such regulations are approved. To that effect, biogas plants have been discussed as a solution to handle the bio residue abundance if such regulations are set in motion (Landbruk 24, 2021). This expected development is essential to keep in mind as the thesis looks at actors who are interested in a transition to an increased usage of manure in biogas production.

2.5. Transportation factors

Globally it is understood that an impactful method to reduce GHG emission will be replacing fossil fuels with advanced biofuels, though it remains a scarce resource internationally. Norway is not an exception. An essential factor to highlight might be that “Norway has through the turnover requirement for liquid biofuels in road transport a high consumption of biofuels per capita compared to most other European countries” (Miljødirektoratet, 2021). Another critical point to highlight is that most countries producing biogas have an already existing natural gas infrastructure, making biogas distribution effortless. Although Norway does not currently have such infrastructure, it should not represent significant concerns since it has a segmented liquefied natural gas (LNG) distribution infrastructure, one that supplies vehicles to consumers inside the industry and ship bunkering. “Is here where synergies can occur with biogas ” (Sund Energy, 2017). Sund energy’s 2017 report, *Muligheter og barrierer for økt bruk av biogass til transport i Norge*, mentions these different markets where biogas could make an impactful entry.

The most promising market for implementing biogas is within road vehicles, in this case, buses. It is reported that around 700 biogas-powered busses are run today, primarily in Trondheim. Potential growth in this sector could occur towards 2030. However, it must be contemplated that competition from electric busses can affect biogas development. Another sector is heavy transport for long distances; filled up gas tanks' weight is significantly lower than batteries per unit of energy, which is a point in its favor. Therefore several producers and distributors have recently set their eyes on the advantages biogas can provide for transport. Some other scenarios the report provides are implementing biogas in the construction industry where machines utilized at construction sites can be run with liquefied gas. For passenger vehicles, the study shows that this market already has different alternatives and that even though it could well be supplied with biogas, there are no significant developments expected in this sector.

How biogas represents an essential solution as GHG mitigator has been addressed, although it faces some barriers that must be taken into account. Within the transport sector, diesel remains a vital fuel supply. As the report from the analytical entity, Endrava As. published in 2019 expounds, diesel buses have a lower cost with NOK9.8/km in comparison with hydrotreated vegetable oil (HVO) and biogas buses' cost of NOK 10.5/km, not to mention that biogas buses sustain a higher acquisition and maintenance costs than diesel. Still, biogas costs remain lower than electric and hydrogen busses being NOK 13.7/km and NOK21.2/km, respectively (Endrava, 2019).

However, agricultural machinery does not fall into the same category; it follows non-road machinery. Total emissions from agriculture machinery represent 343,000 tonnes CO_2 eq., mainly coming from tractor usage. Klimakur 2030 estimates that the 155,671 registered tractors in agriculture produce 90% of the total machinery industry emissions (Norges Bondelag, 2020). "This is why it is important to utilize bioresources as efficiently as possible in the effort to transition to a low-emission society. The use of sustainable bioresources could potentially yield considerable reductions in emissions from industry and transport and also provide a basis for new industries" (ENOVA, 2020).

There is a crucial factor to address within this section, one that could help accelerate biogas production: transport of biowaste to end-users. This is one of the most impactful cost drivers for co-treatment plants; costs related to manure collection are significant. Furthermore, it involves transporting unnecessary water if the manure is not dewatered first. "Livestock manure is a small energy-rich substrate with low dry matter content (2-5%)" (Landbruksdirektoratet, 2020). Therefore Landbruskdirektoratet emphasizes the importance of a transport subsidy since it can contribute to the delivery of manure and biowaste to those who require it. It is estimated that if untreated bio residue is transported over distances over approximately 45km, the resulting GHG gas emissions from transport would be higher than the possible emission savings by the bio residue replacing mineral fertilizer. The report also remarks on not needing to establish a separate support scheme for the transport of biowaste but instead seeking to increase the delivery of livestock manure subsidy rate to biogas plants. “To a level that also reflects the possible additional costs of transporting bio waste out of the biogas plant. ”(Vista Alaysis, 2019, as cited by Landbruksdirektoratet, 2020). Such incentives can be provided from ENOVA.

2.6. Actors at play

It comes as an understatement that biogas production in Jæren will not likely occur on its own. For such a transition to happen, it will be necessary to turn to allies to boost biogas production in the area. This section centers on identifying the current and possible actors willing to invest and explore the possibilities of biogas in Jæren that could make up for a greener change in the region. From subsidies that could be provided from the state (ENOVA), private company alliances to small biogas plants in the area regardless of their economic/land limitations.

2.6.1. Enova

An important actor that businesses must consider before planning to install renewable technology is Enova. Enova is a Norwegian state-owned enterprise by the Ministry of Climate and Environment that “contributes to reduced GHG emissions, development of energy and climate technology and strengthened security of supply” (ENOVA, 2021). It receives its funding from the Energy Norwegian Fund, financed by the government budget and a surcharge on the grid tariff.

Norway's path towards achieving the Paris Agreement demands lowering emissions in every industrial field. The Norwegian government recognizes that an essential solution for this transition to happen lies under the adoption of renewable energy, but that such changes come along with an economic impact. Therefore ENOVA was established in 2001 to assess the development of renewable technology in the private sector in such a manner that companies do not hasten their decision towards technologies that might harm their financial viability.

To do so, ENOVA's primary goal, to fulfill Norway's climate commitment for 2030, has drawn attention to a significant contributor of greenhouse emissions in Norway, the transport sector. Even though this sector is not included in the EU Emissions Trading System, it represents about one-third of GHG emissions in the country (ENOVA, 2020). An important factor that will be further explained in the section below regarding the impact that it plays within biogas production in Jæren.

Reducing emissions from the transport sector has motivated Enova to target battery-electric solutions, hydrogen, biogas, infrastructure, energy efficiency measures, and logistics solutions. Hydrogen has had the most benefit from the previously exposed technologies. As of 2020, Enova has invested NOK 260 million where three ships were acquired as well as the infrastructure upgrading that such entail. Said subsidy not only contributed to achieving Norway's lower emission scheme but has also contributed to incentivizing other companies: "Several consortiums have also been awarded support through Pilot-E, a collaborative funding scheme from the Research Council of Norway, Innovation Norway and Enova to develop and mature concepts using hydrogen as an energy carrier in the maritime sector" (ENOVA, 2020).

2.6.2. IVAR, LYSE and FELLESKJØPET join forces

Ivar, Lyse, and Felleskjøpet union represent an essential player in developing biogas production in Jæren. The Inter-municipal water, sewage, and waste disposal in Rogaland, by its acronym in Norwegian (Inter kommunal Vann, Avløp renovasjon i Rogaland, IVAR), is located in the business area of Grødaland municipality of Hå in Jæren. It is the largest waste and chemical treatment plant in Norway. The plant treats daily wastewater from the neighboring town of Varhaug and industrial sewage from Kviamarka food park and Norsk Protein AS. The current biogas production at the facility is provided to the energy company Lyse Neo. Lyse operates Norway's most extended land base gas network. The company started at the beginning of the 20th century by establishing the first electricity plants, helping to boost industrialization and modernization in Norway. In 1999 after new legislation on the energy industry sector, the company added e-plants, giving way to the foundation of Lyse Group. “Today Lyse is wholly owned by 14 municipalities in South Rogaland " (LYSE, 2021), among them Hå.

The production at the moment mainly consists of waste and sludge from treatment plants (Mekjarvik, Oltedal, Vik, and Grødaland) and food plants that are allocated around the region (South Jæren). IVAR “produces approximately 4,500,000 m^3 every year. This represents the fuel consumption of 4,000 private cars with an annual driving distance of 15,000 km" (IVAR, 2021). The production occurs through the anaerobic bacteria process, where CO_2 is separated and sold to Lyse Neo. Lyse’s natural gas collected from the North Sea gets mixed with the provided biogas from IVAR and distributed through Lyse’s already existing insulated pipes, used for heating and production processes (LYSE, 2021). Lyse’s and Ivar’s partnership began in 2002 and currently produces 160 to 170 GWh every year (Lyse, 2021).

The collaboration between Lyse and IVAR will be venturing deeper into biogas production in South Jæren, as they join forces with the Norwegian agricultural cooperative, Felleskjøpet (Bondekompaniet). Felleskjøpet, being a significant retailer of agricultural operating equipment, seeds, grains, and fertilizer, sees how vital its contribution can be. Sustainable changes will entail restructuring and production within small and big farmers, committed to making adjustments by being part of a greener change that helps reach the environmental treaties. “By reducing costs and improving the utilization of resources in interaction with new technology, it will provide great opportunities for both the company and the industry as a whole” (Felleskjøpet, 2021). Their approach throughout this venture is providing advice to the farmers regarding the most suited type of fertilizer and practices that the farmers need to implement on their land, a more climate-friendly type of food depending on the type of animals the farm is raising and the most suitable technology that could be implemented according to the farm. Most of Felleskjøpet’s products (grains, fertilizers, equipment, etc.) are carried through land and sea with fossil fuel heavy transport every day of the year, representing 60% of the company’s CO_2 emissions, being the main reason for their involvement regarding biogas in Jæren, along with IVAR and Lyse.

2.6.3. Greve Biogass, AIR LIQUIDE Skagerak, Nortura and Tine: A second alliance

Greve Biogass, Air Liquide Skagerak, Nortura, and Tine form the second alliance targeting biogas production in Jæren; each company plays an important factor in gas, food, agricultural production and energy conversion.

Grenland Vestfold Biogass AS (GREVE) is owned by ten municipalities located in Vestfold and Grenland in East Norway. The company was founded in 2013 to contribute to green value creation in the region, based on biogas production from organic waste (livestock manure, sludge, and organic waste) and "climate-friendly production of food from fertilizer and green CO_2" (Greve Biogass, 2021). The interest is notable, as it was previously explained in the *State of Norway* section; the development that the company has made through their factory *Den Magiske Fabrikken* has drawn the attention of new investors, one of them being the Norwegian-French gas enterprise Air Liquide Skagerak. Before 2017 the company was formerly known as Skagerak Naturgass, until they joined forces with Air Liquide. Air Liquide Skagerak distributes natural gas and biogas to the industry, transport (maritime and land-based), and public construction (Biogass Norge, 2021). Their catalog is based on the market and distribution of bio and natural gas; it also owns and operates associated facilities to the network (Skagerak Energi, 2021). The company is currently known for being an active player in the biogas segment through strategically targeted position, expertise, and position infrastructure. The company already has biogas filling stations for transport in Telemark, Vestfold, and Østfold. Greve Biogass and Air Liquide Skagerak have had positive results from their alliance in Den Magiske Fabrikken; Greve AS, leading the operation and maintenance of the plant and Air Liquide as the distributor of the gas (No Waste, 2021). Such positive results were the catalyst to expand production to Jæren. However, as of December 2020, the total cost of the project was uncertain. Regardless, a petition has already been sent requesting economic support from Enova (Karlsen, 2020).

Recently Nortura SA has also stepped into the process. The food production cooperative (meat and egg) was established in 1911 due to farmers joining forces to work their way up into the Norwegian market by developing an integrated value chain and brands based on supplies from farms (Nortura, 2021). Today Nortura is one of Norway's strongest food manufacturers; their aim continues on selling their members eggs, meat and wool, so their members get the best financial results from their production; more recently, their vision is adapting their target towards a greener and eco-friendly future. “Biogass Norway is an important organization for the future, and we hope that through our membership we can contribute to influencing farmers and agriculture’s place in the value chain for biogas” (Ane Guro Danielsen, project manager strategic innovation at Nortura, as cited by Nortura, 2021). An example of changes being made is Nortura’s Tønsberg plant, where since the summer of 2020, 51% of the natural gas has been replaced with biogas, contributing 20% of the plant's heating, “estimating to account for 2284 tonnes of CO_2” (Nortura, 2021). Nortura’s efforts regarding biogas do not cease here; as of recent years, the cooperative dwells into the possibility of implementing biogas for transport and factory operations from their members' manure. The company envisions reducing emissions within their transport to 80% and cutting all fossil fuel sources within the industry by 2030. Thus it is understood that biogas represents environmental benefits; it can also help reduce pressure on manure spreading and cattle regulations on Jæren, hence the interest in joining forces with the previously mentioned companies (Nortura, 2021).

Another important player within this alliance is Tine SA. The company is the largest producer, distributor, and exporter with an extensive catalog of dairy products and a long trajectory since 1856. As part of their vision, Tine is currently seeking biogas opportunities in Jæren. Positive results shown by Greve Biogass have been enough stimulation for the company to be interested in joining the alliance. As dairy producers, they understand the challenges GHG impacts the industry primarily related to storage and handling of livestock manure, not to mention emissions caused by the products’ transportation. “We envisage building it on the Greve model where the farmers deliver fertilizer and get back bio-residue that is adapted to their needs and can also reduce the use of artificial fertilizer” (Bjørn Malm, as cited by Sola, 2020). Plans regarding biogas implementation in their company go further and include heating, heavy transport vehicles, utilizing CO_2 for GHG cultivation, and utmost importance; to return the bio residue to the farmers to help them reduce commercial fertilizer purchases.

The alliance expects the future plant to take in as much as 500,000 tonnes of manure (representing approximately seven times more than the current Greve Biogas production in Vestfold). It is estimated that the production might generate 100GWh. Thus the companies have a solid trajectory in different aspects of the industry; such advances will entail additional financing; therefore, an application has already been submitted to ENOVA and is under deliberation.

2.6.4 Bioenergi Finnøy: Upstart challengers

The biogas interest does not only revolve around big enterprises; a few notable small companies are trying to make their way through as well. One such upstart is Bioenergi Finnøy. The town of Finnøy (formerly a municipality in Rogaland) is located northeast from Stavanger; due to the town's trajectory and enthusiasm of developing biogas in Rogaland and other meaningful solutions to reduce emissions, this research finds it of utmost interest to present what small companies are envisioning around the county.

In 2009 Landbruksdirektøren i Rogaland (Rogalands Agriculture Agency) disseminated their 2020 goals, where 60% of livestock manure in Rogaland would be used in biogas production. The news came as an incentive to some farmers of Finnøy and Rennesøy due to the amount of manure the region produces and its large production of greenhouse-grown tomatoes, where excess CO_2 from the biogas production process can be utilized. "The idea was to produce biogas with livestock manure as raw material (substrate)" (Innovasjon Ryfylke, 2021). The same year Bioenergi Finnøy AS was established, now known as Innovasjon Ryfylke. The board was formed by 26 shareholders, among them Finnøy Municipality, Ryfylke IKS, Rogaland Bondelag, and local companies. The engagement was such that immediate visits to Denmark were made due to the country's progress involving biogas production. It was decided that Denmark's plan was the most suited to adopt for Finnøy and Rennesøy in terms of their previous success using the same mixed substrate (Innovasjon Finnøy, 2021). From the knowledge gathered, they planned to build a biogas plant next to the Lauvsnes Gartneri (horticulture with an extension of 15 acres) to create a synergy between agricultural and biogas production. The greenhouse would need 7 to 8 GWH of gas every year, which was learned to be impossible with the benefit schemes and technology.

A petition for subsidies was sent to ENOVA; the proposal sent back constituted 30% of total costs, an amount that was considered to be insufficient. Subsequently, the offer was declined, which led the project to be put on hold.

In the words of the coordinator of Innovasjon Ryfylke Kristian Spanne, "The production cost per KWh is around NOK 0,55. If it were to be sold at a price of NOK0,60, there would still be a profit margin. This is a much lower price than what it is currently being sold for in Eastern Norway, that being NOK 0,80. Unfortunately, we still have not found someone willing to pay over NOK 0,50." (Innovasjon Ryfylke, 2021).

Regardless of the struggles the Ryfylke region is facing towards implementing biogas in the area, the will for this upstart initiative has remained for over a decade and is now seeing promising developments. Contrary to the strong alliances formed by large companies, as was explained in the sections above, Innovasjon Finnøy comes as an example that regarding the limitations small groups might face regarding biogas, new and more sustainable solutions can be addressed during the process. For instance, small communities willing to develop biogas in the area, where biowaste is returned to the farmers to fertilize their fields, CO_2 is given for horticulture purposes, and biogas production replaces the utilization of natural gas in the area. This is evidence that the purposes of biogas can be served in different aspects of the economy.

2.6.5 Norges bondelag

Norges Bondelag, or the Norwegian Farmer's Association known in English, is a politically neutral business organization for farmers. It promotes common causes and safeguards the countryside's economic, social and cultural interests (Store Norske Leksikon, 2021). Since the organization's founding in 1896, its objective has centered on finding solutions to problems farmers might face regarding agriculture within many fields, such as international food market competition, social development, industrialization, and international politics, to name a few.

Although membership grew at a slow pace in its early beginning, the farmers' union managed to overdue political results in their favor, as shown with the 1950's Canalisation policy

(Kanalisering Politiken). The policy strengthened the economy respecting grain production and moved most animal husbandry production to the fjords and mountains, creating essential changes for the agricultural community.

In 2010, concerning population growth nationally and internationally, the rise of food market prices and climate crisis had created the current agricultural policy goals of increased national food production (Norges bondelag, 2021). However, it should be noted that to this day, the discontent regarding an income gap is very palpable from the farmers; at the moment, it goes to show due to the recent manifestations in May 2021.

Even with such discontent present, Norges bondelag along with other farmer's associations Norsk bonde (Norwegian Farmers) and Småbrukarlag (Small farmers association), "have entered into a climate agreement with the government, to reduce GHG emissions and increased carbon uptake in soil by 5 million tonnes of CO_2 eq. from 2021-2030" (Norges Bondelag, 2020, pp.1), which goes in favor not only regarding the Norwegian government's emission reduction goals but to the agricultural community as well. Such an agreement will increase value creation and sustainable food production with lower gas emissions. "Norges Bondelag believes that the time has come for climate policy that lays the foundation for future value creation and strengthens competitiveness for Norwegian agriculture by improving Norwegian food production" (Norges Bondelag, 2020, pp.2). Thus, production and use of biogas are being identified as a vital measure to reduce agriculture's direct and indirect GHG emissions; the association believes conditions for the use of livestock manure to biogas production must be further improved. This initiative can be addressed as setting a precedent on the interest for future biogas development or even necessitates it (Norges Bondelag, 2020, pp.23).

Norges Bondelag works through memberships, which has counted around 62,000 members for the last few years, with 515 local teams and 17 county teams (Norges Bondelag, 2019). Most of the association's information respecting their latest news is reported through their website, as well as condensed educational, agricultural material. The headquarters in Oslo is also responsible for publishing the newspaper *Bondebladet*, which is available to its members. The paper also has a subscription agreement with the cooperative organizations Tine and Nortura, to name a few, reaching a large number of farmers from their 48 yearly editions (Bondebladet, 2021).

It is clear how vital the role the association plays in holding bilateral communication between farmers and the government. Furthermore, it suggests how the association is aware of the adjustments that must be made to accomplish a vital transition, one that biogas production has an important role to play.

2.7 Biomass

"*Biomass is energy from the sun captured through the natural processes of photosynthesis*"
(Williams, Dahiyu & Porter, 2015, pp.6)

Biomass is known to be the earliest energy feedstock. It has also been the primary one for most of humanity's existence, beginning with humankind's discovery of fire, believed to have occurred 250,000 years ago (Coley, 2008). Its use is noted from animal work for agricultural purposes to its implementation for cooking and heating. In recent years biological material and animal waste have been employed for energy conversion, known as bioenergy. Such production represents an opportunity for economic growth from a micro-level approach, additional income, and small-scale renewable energy production for farmers to a macro level in terms of creating a new industry for the region while helping Norway to reach its Paris goal commitment.

Unlike fossil carbon fuels, whose primary source arises from the geological degradation of plants, bioenergy´s content lies in the implementation of the energy caused by the natural process of photosynthesis induced by the sun. Bioenergy variants are power, heat, solid, liquid, and gas fuels. The application of said forms can also be called biopower.

Biopower can be produced either jointly in the combustion of other fossil fuels (coal, gas, or other fuels) rather known as co-firing, or alone through its own fermentation process. The great majority of biogas plants are direct-fired systems, which is when the feedstock is set to be burned in a boiler to make steam that will spin the turbines connected to electric generators. The heat generated through biopower not only could help produce electricity but can also be used directly in the industry: “The steam generated through combustion of biomass can also be used to directly power mechanical processes in industrial settings” (Dahiyu, 2015, pp.6), and such implementation is known as biofuel. Biofuel can take three different forms: solid, mainly used for heating, liquid, and gas biofuels. These last ones are generally obtained from gasification, torrefaction, pyrolysis, and fermentation.

Biofuel can be classified into four different categories.

- First generation: produced from starch crops and sugars, constituted mainly from corn and soybeans.
- Second generation: its production is generated from the residual, no-food (animal waste), parts of crops, wood, grasses, municipal waste (sewers).
- Third and fourth: Also known as green biofuel, whose main component is algae.

Figure 2 demonstrates how different feedstock, through different generations, can create specific products derived from the biomass.

Generation-wise biomass distribution with its features.

	1st generation	2nd generation	3rd generation	4th generation
Feedstock	Sugar, starch crops, vegetable oil, soya bean, animal fat, straw	Wood, agricultural waste, municipal solid waste, animal manure, landfills, pyrooils, pulp sludge, grass	Micro algae biomass	Genetically modified crop
Product	Biodiesel, sugar alcohol, corn ethanol	Hydro treating oil, bio-oil, FT-oil etc.	Algae oil	Biofuel
Advantage	Environmentally friendly, economical and socially secure	Not competing with food Environmentally friendly advanced technology under process to reduce the cost of conversion	Availability of high value protein and nutrients, residual algae for jet fuel animal feed	Easily captures CO_2 and conversion to a carbon neutral fuel
Disadvantage	Limited feedstock, blended partly with conventional fuel	Acidic, viscous, high oxygenates content in pyrooils	Slow growth of algae, extraction of algae oil is difficult and costly	—

Figure 2. Generation-wise biomass distribution with its features. (Hornung, 2014, pp.6)

The primary industry in the communities of Vigrestad, Nærbø, and Varhaug is cattle and sheep farming. This thesis has focused its scope on producing biogas from animal waste, or mostly known as manure. Biogas production could be a technology worth developing among the small farm owners.

2.7.1 Biogas

As previously mentioned, Biogas technology is well known to be an old energy conversion method. Nowadays, its advantages as a clean energy production to help mitigate the existing climate crises caused by vast consumption of fossil fuels and the world population increase have led to encouraging its production. In addition, biogas could help reduce GHG emissions and serve as a waste management solution due to animal husbandry growth and as a source of income for the farmers.

Biogas is typically formed by 60% methane (CH_4) and 35-40% carbon dioxide (CO_2) along with other gases; ammonia (NH_3), hydrogen sulfide (H_2S), hydrogen (H_2), Oxygen (O_2), nitrogen (N_2) and carbon monoxide (CO) (Scurlock, 2017). However, the composition might vary depending on the feedstock.

One way of producing biogas is through Anaerobic Digestion (AD) of various organic wastes; municipal solid waste, food waste, industrial waste, sewage sludge, animal manure, and agricultural residues, for instance (Abdeshahian et al. t, 2015).

2.7.1.1 Anaerobic Digestion

Anaerobic digestion (AD) can be construed as the degradation of organic compounds to simple substances by interacting with nutritional and environmental microorganisms while excluding external electron acceptors such as oxygen. Said process subsequently releases two main products, one a renewable energy vector rather known as biogas, whose chemical components have been previously explained above, and a solid decomposed matter rich in nitrogen and carbon, successfully used as fertilizer, named: digestate. The benefits provided by the implementation of AD contribute as an energy producer but also assist in reducing GHG emissions (Panico et al., 2014).

The AD process is executed in a reactor that will help generate biogas from liquid or solid waste. The digester's physical shape can vary from a covered lagoon system (usually implemented in farms with small land space) to a factory prefabricated turn-key installation. “The digester is covered or encapsulated to enable biogas capture for flaring, heat and/or power generation or feeding biogas into a natural gas network.” Given that this energy conversion process transits in a closed environment, it reduces methane emissions commonly generated from the spreading of the manure without treatment that has been stored through the year in the farm and is immediately spread in the land (Carbon limits, 2019).

The anaerobic digestion process is conformed by four key biological stages; Hydrolysis, Acidogenesis, Acetogenesis, and Methanogenesis. These steps will be described in the section below.

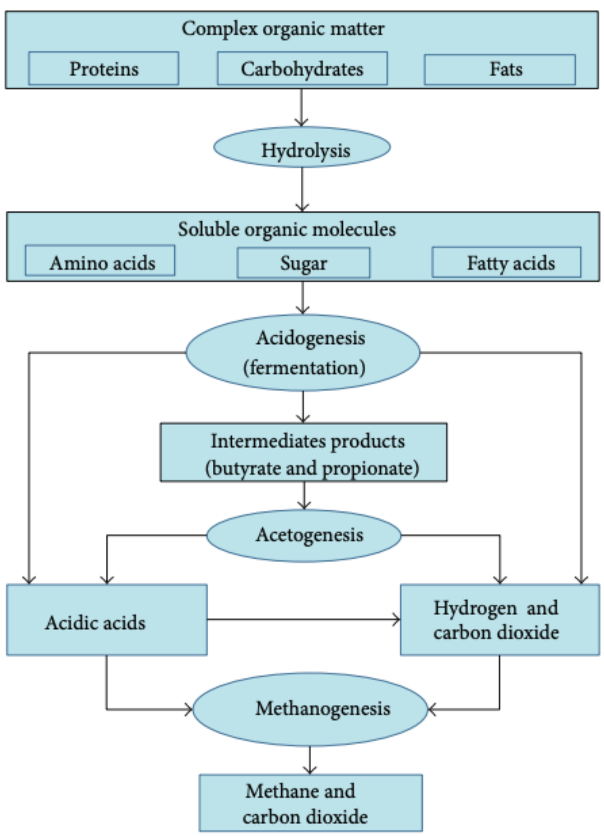

Figure 3: The key process stages of anaerobic digestion (Abdelgadir et al., 2013)

2.7.1.2 Hydrolysis:

Hydrolysis is the first step within Anaerobic Digestion. Although it is a relatively slow process, its importance is vital within the process since it can limit the rate of the overall digestion process. "Hydrolysis refers to the cleavage of chemical bonds by the addition of water. Cations and anions react with water molecules, altering pH in the process to create a cleavage of H–O bonds" (Anukam, et al. 2019 pp.3). To further explain, throughout the hydrolysis process, large sugars, fats, and proteins molecules segregate different enzymes that catalyze the reduction of those into smaller pieces that can be easily absorbed by microorganisms and be used as a source of energy and nutrition. In addition, there are different enzymes segregated by some microorganisms excreted by the fermentative bacteria, known as extracellular enzymes specialized in other substrates. These are divided into different groups, as shown in Figure 4.

Enzymes	Substrate	Breakdown Products
Proteinase	Proteins	Amino acids
Cellulase	Cellulose	Cellobiose and glucose
Hemicellulase	Hemicellulose	Sugars, such as glucose, xylose, mannose and arabinose
Amylase	Starch	Glucose
Lipase	Fats	Fatty acids and glycerol
Pectinase	Pectin	Sugars, such as galactose, arabinose and polygalactic uronic acid

Figure 4: Important groups of hydrolytic enzymes and their functions. (Schnürer & Jarvis, 2010)

The speed of decomposition within this stage relies significantly on the nature of the substrate and its size, along with the sensitivity to temperature fluctuation. It should be noted that the majority of the molecules within this stage must be further reduced in size, leading to the next step of the anaerobic digestion process, i.e., acidogenesis.

To summarize, "hydrolysis serves the purpose of rendering organic macromolecules into their smaller components, which in turn can be utilized by acidogenic bacteria" (Meegoda, et al. t. 2018, pp.4).

2.7.1.3 Acidogenesis

This step is better known as the fermentation stage. The soluble compounds assembled throughout the hydrolysis phase are degenerated by fermentative microorganisms and turned into ammonia, carbon dioxide, hydrogen, and organic acids. The most important acid in this stage is the CH_3COOH, and it is the most significant organic acid used as a substrate by CH_4-forming microorganisms" (Anukam et al., 2019 pp.4).

2.7.1.4 Acetogenesis

This phase can also be called dehydrogenation since the H_2 gas formed from the waste product of the acidogenic stage is inhibited by the metabolism of acetogenic bacteria. "However, H_2 gas can be consumed by CH_4-producing bacteria to function as hydrogen-scavenging bacteria that can convert some of the bacteria to CH_4". Acetogenesis is as essential as the previous stages of the AD process; it determines the efficiency of biogas production "since approximately 70% of CH_4 is formed through reduction of CH_3COO^-" (Anukam et al. 2019 pp.5).

2.7.1.5 Methanogenesis

As the last stage of the Anaerobic process lies methanogenesis. Within this phase, the methanogens bacteria convert CH_3COOH and H_2 into CO_2 and CH_4. This type of anaerobes bacteria is highly vulnerable to environmental changes and small amounts of oxygen. "Organic pollution load in terms of chemical oxygen demand (COD) or biochemical oxygen demand (BOD) is reduced considerably by the anaerobic process in the methanogenic stage; hence efficient methanogenesis is usually construed to mean efficient elimination of carbonaceous pollution" (Anukam et al. t. 2019 pp.6).

The digestion can happen in wet and dry systems, the difference being the moisture content (dry having lower moisture content). An advantage of the dry system is that it requires less energy input, but more water is also needed for this, which results in a bi-product digested needing to be separated. Biogas can be used locally where it is produced to provide heat and electricity, or it can be upgraded to biomethane to be directly injected into natural gas pipeline networks (Scurlock, 2017).

The AD process from animal manure has shown to be an effective solution for reducing GHG emissions from air and water and more substantially as a more effective way to recycle and return materials into the farming systems. Moreover, although biogas production from AD effective results has increased in the last decades in Europe, as was explained in section *2.1 State of Biogas in Europe*, "there are only a few farm-fed AD plants in Norway, and their capacity is about 1% of the theoretical potential for manure" (Pettersen et al. 2017, Lyng. 2018, as cited from Carbon Limits, 2019, pp.5). A scenario that could possibly change due to Norway's target of the utilization of 30% of manure from livestock for biogas production by 2020 (Landbruks & Matdepartementet 2009, as cited from Carbon Limits, 2019, pp.5).

2.8 Potential and different scenarios

A report by NORCE (Gitlesen et al., 2019) looked into three different scenarios of biogas production in Jæren. The first with no biogas, the second with biogas where all the manure from the livestock is separated at the farm into two different fractions, a dry and wet one. The dry fraction will then be transported to a centralized hub for treatment. The third scenario is similar to the second scenario, but here a farm instead that would use the wet fraction is also included. The report used a life-cycle assessment method to identify potential emission reductions from different scenarios. Economic benefits were also estimated to try to predict whether farmers would be willing to make the changes from the different scenarios. They found substantial reductions in emissions per ton of manure are possible with the second and third scenarios, with the third even more so than the second (Gitlesen et al., 2019). Most of these reductions come from the reduced storage time of methane. In regards to the economic benefits, the results were somewhat mixed. Although it shows that the scenarios where biogas is used are more expensive for farmers, it depends on several uncertain factors. These include how investment and rental costs will change in the future and other cost factors, like whether they have existing transportation costs associated with manure or whether they will be expected to have these costs in the future. Hence this could be profitable or not depending on various factors (Gitlesen et al., 2019).

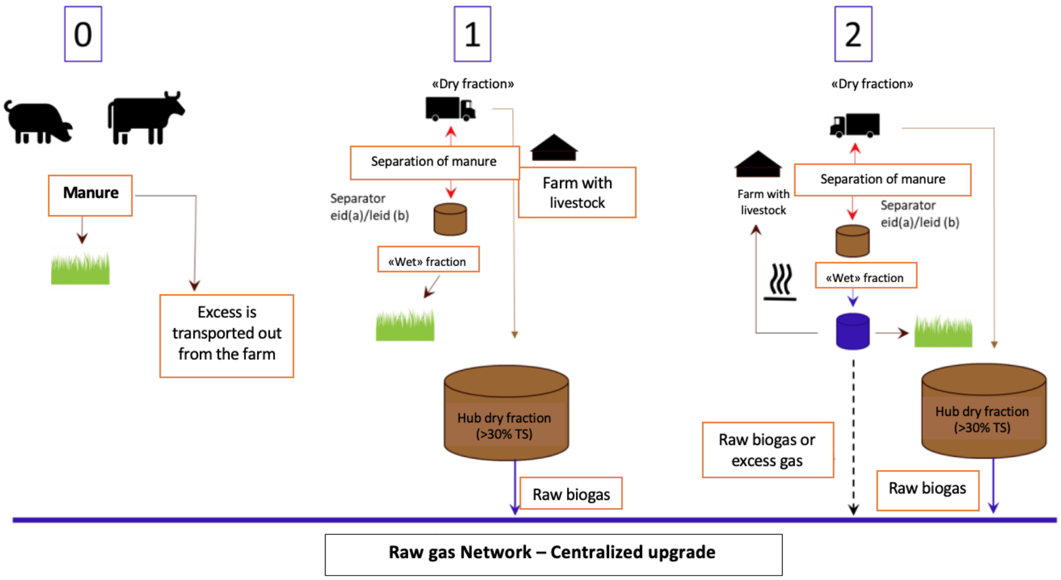

Figure 5: Raw gas network - centralized upgrade. The figure above defines three different scenarios as to how biogas production could transcend. Scenario 0 does not involve the separation of fertilizer. Scenario 1, separation process exists in both weather and dry manure. The wet fraction is implemented in the farm, and the dry factor is carried to a centralized hub for biogas production. Scenario 2 separates manure, local biogas production from wet fraction, and the transport of dry fraction to a centralized hub for biogas production. Scenarios 1 and 2 can also be divided into a and b, where a) the farm owns its separator and b) the farm rents a separator. (Source: NORCE, 2018, pp. 12, Translated from Norwegian to English by Nataly Coronado)

2.9 Policies and public support

In the 2018 report by Fylkesmannen, Rogaland fylkeskommune looks at what implementations they can make to facilitate biogas production in Rogaland. One of these is public support for filling stations for biogas. The reason for this is to help the biogas infrastructure development in the early stages and speed up its diffusion. Facilitating cooperation between different actors in the biogas value chain is also a vital solution highlighted in the report, which Rogaland fylkeskommune has previous successful experience with. It is essential as it strongly implies competence in this area. Procurement policies to favor biogas purchases are also a solution to secure a stable market for biogas. This might also help mitigate some of the concerns around cost uncertainty mentioned earlier. There will at least be a stable market acting as a positive counterweight to the cost uncertainty. Reduced toll fees for biogas is another solution that can help facilitate biogas development by reducing the "total cost of ownership." Basic research and development is also a policy that is recommended in the report (Rogaland fylkeskommune, 2018).

An exciting policy proposal mentioned in the report is to convert from natural gas to biogas for all heating of Rogaland fylkeskommune's public buildings. The current usage in Rogaland Fylkeskommune is 5.2GWh of natural gas. Here the goal is not necessarily to achieve significant cuts in GHG emissions, as the emission reductions considering the energy used are not that large, but rather to help create a stable market for biogas and increase the viability of biogas production (Rogaland fylkeskommune, 2018).

3. Problem Statement

There is no doubt that there is potential for biogas production to accelerate in Jæren. However, with this comes both opportunities and challenges. If biogas production is to become a viable option for Jæren, climate and economic compromises might have to be made. As we saw in the literature review, the scenario where the highest amount of emissions were reduced was also the least attractive option for the farmers.

Norges Bondelag believes that they could benefit if a transition to biogas in Jæren would occur, which is very important as they would need to make the necessary investments for this to happen (Norges Bondelag, 2020 p.1). This is unlikely to occur if the economic costs outweigh the financial gains. Cost uncertainty is also a significant factor here, making the farmers err on the side of caution and not make the necessary investments, even if there is reason to believe economic gains could outweigh costs. Subsidies have proven to be effective measures taken by the regulator to promote sustainable domestic and corporate practices in Norway, as was the case with electric vehicles.

However, if the transition does not occur, Jæren still must implement measures to curtail their emissions. They could very well end up in a worse scenario than if the transition had happened, as these measures would have to impact farmers' daily operations, given that a significant portion of the emissions from Jæren come from agriculture. As of 2019, Rogaland's agriculture industry reported emissions that reached 660,000 tCO_2 representing 16% of the county's total emissions. Nationally, agriculture signifies 12,1% of the country's emissions; therefore, it is understood that Rogaland's emissions are significantly high within this sector. It should be noted that South Rogaland (Jæren being part of) has a much higher record of emissions than Northern Rogaland, "which is reflected in the fact that emissions were 520,000 tCO_2 and 140,000tCO_2 respectively in 2019" (THEMA, 2020).

When researching this thesis, these conflicts will be essential to keep in mind. Furthermore, finding solutions to overcome these problems will be crucial if a lasting transition with real impact occurs.

3.1. Research Questions

After analyzing the previously given literature review along with the aim of this thesis, it was determined that the following research questions would be beneficial in regards to a more successful research development:

1. ***Is biogas technology being domesticated by South Jæren farmers?***

With more than ten years of production, Biogas is not a recently emerging technology in Jæren. However, the amount of time that biogas has been developed in Jæren will allow this research to explore if the technology has already been exploited to its total capacity from a micro-macro perspective. From the micro-level, how domesticated the cattle farmers are in their daily routine, and at a macro level, analyzing the benefits it provides to Jæren's society regarding energy production and how it plays an essential factor in the Norwegian government's carbon emission goals for 2030.

2. ***What is the potential of biogas development in Jæren?***

As previously mentioned, some companies have been working with the implementation of the technology. As of December 2020, some others are being created by already existing alliances, according to Jærbladet (Myklebust & Sandsmark, 2020). It could be reasonable to assume that the construction of these plants would entail being in touch with the local farmers; therefore, it is essential to investigate how the relationship between farmers and companies helps optimize the biogas production in the area. It will be relevant to understand how both parties are conducting this transition and, more so, examining if farmer's needs and wants are being met.

3. ***What will the advantages be regarding the production of biogas in Jæren and the challenges it might face in Jæren and its farm owners?***

Various entities have addressed biogas production as a positive strategy to generate employment in every aspect, hence the name bioeconomy. Therefore it is vital to address if biogas could potentially be a catalyst of Jærens' economy and the region's energy making while reducing energy cost for farm owners and more so could it also be a solution to mitigate methane emissions and to avoid phosphorus build-up in the fields.

4. ***What will the policy implications be regarding biogas production in Jæren as a whole and individually for small farms?***

Biogas could allow the next generation of farmers to remain viable in the face of tightening restrictions regarding animal husbandry. Thus it is crucial to inquire if biogas could incentivize farmers and future generations to remain as producers and more so if biogas could potentially be the needed solution: to analyze if such plans will not harm the economy of farmers in the development of the project.

4. Research Theory

It is crucial to evaluate the role that biogas can play in the area of Jæren and how viable it can be, not only for the producers and consumers but also for environmental benefits. To achieve a better understanding, it is of great importance to examine the factors that might accelerate or repress the technology. Therefore, it was determined that the best option for the development of this study lies within the Multi-level perspective (MLP) theory.

4.1 The multi-level perspective

A goal-oriented transition doubtfully will manage to reach its target if the different scenarios and actors surrounding the problem are not taken into account. Within sustainable transitions, the multi-level perspective framework is often utilized to discern how said factors interact with one another. The MLP contributes to a better understanding of system transitions (Prayag & Ozanne, 2018). "MLP recognizes that technologies are embedded within wider social and economic systems, and thus the focus should be to understand systems innovation and change" (Smith et al., 2010). The MLP comprehends transitions that occurred through the interplay between three analytical levels: socio-technical niches, socio-technical regimes, and socio-technical landscapes.

4.2 Socio-technical niches

Socio-technical niches are envisioned as an experimental level where innovations are developed and put to the test. Such advances manage to be generated due to the still-pressure absence from the socio-technical regime. The Niche involvement within the MLP stands as a provider for systemic change since "they are willing to support emerging innovations" (Geels, 2011). In addition, Niches grant a secure development for these new alternatives "whose performance may not be competitive against the selection environment prevailing in the regime" (Rip,1992, p. 91; Kemp et al., 1998 as cited by Smith, Voß, Grin, 2008 pp. 440).

According to Kemp (Kemp et al., 1998; Schot and Geels, 2008), the development of the niche can be divided into:

- The introduction of expectations or visions to make the emerging innovation known to collect financial aid.
- Construction of social networks.
- The recollection of information is based on different dimensions and processes.

Socio-technical niches are not strictly addressed as technological advances. It can also be envisioned as entities that question the already existing norms set by the regime, intending to advocate for it to be modified. To prevail, constant interaction between the actors and the innovation is required. Such action will accelerate its progress or, in other circumstances, cause its collapse (Vähäkari et al., 2020).

As previously discussed in section 2.6, Actors at play, companies are interested in launching biogas production in Jæren. However, for purposes of this thesis, small farm owners had been identified as the socio-technical niche. New manure regulations have caused Jærens small farm owners to question the viability of remaining in the agricultural industry. A decision that can be varied on the assumption of them becoming part of the biogas production in Jæren. Therefore the interest of this research is to inquire about the viability of Jæren's farm owners as producers or partners in this transition.

"Niche is the third analytical level of the MLP. On the niche level, experimentation and radical innovations can be developed outside of the immediate pressure from the regime."
(Geels, 2002 as cited by Vähäkari et al, 2020 pp.4).

4.3 Socio-technical regime

According to Geels (2011), the socio-technical regime states the framework within an existing socio-technical system. Geels further explains that regimes comprise the multi-actor network of social groups who populate an industry and adhere to a "semi-coherent set of rules" (Geels, 2002, p.1260). Adrian Smith also addresses the concept of the socio-technical regime as support, "structures constituted from a co-evolutionary accumulation and alignment of knowledge investments, objects, infrastructures, values, and norms that span the production-consumption divide." (Smith et al. 2010 pp. 441). This research has identified as a regime the existing and prevailing economic gains brought up by Norway's natural gas and oil production.

4.4 Socio-technical landscape

The socio-technical landscape envisions the different elements that might affect, aid, or influence both the regime and niches perspective through the lens of scientific developments, climate change, governmental developments, economic changes, social movements, etc. "Landscape changes are a source of pressures for change on the regime level; they prompt responses from within the regime; they generate opportunities for niches. At times, landscapes can work to reinforce regime trajectories" (Smith et al. 2010, pp.441). This research identifies the socio-technical landscape within the impact that the current worldwide climate change situation is in and how it is known agricultural emissions play an enormous role in the matter. Therefore it is vital to analyze the current atmosphere between the small farm owners and biogas technology.

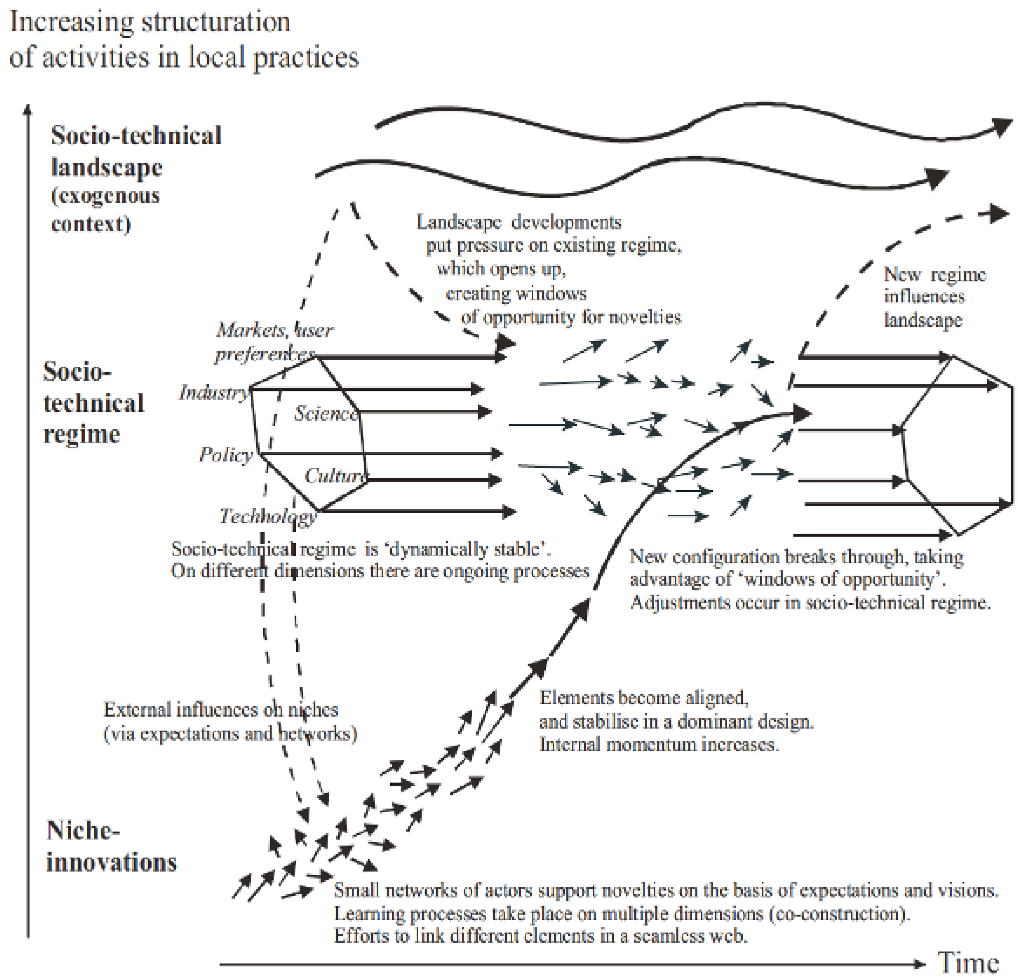

Figure 6: Multi-level perspective on transitions (Geels 2011, pp.28)

Identifying the different actors and their interplay within the transition is essential to propose an effective change. The landscape, meaning greener change, is putting pressure on the government to reduce GHG emissions. However, is the regime focused on cutting emissions? They indeed claim to be, evidenced by the promised cuts in the agricultural sector. Still, at the same time, they are subsidizing farmers to increase red meat production to make the country more self-sufficient. What do farmers think in this situation?

The Norwegian government has not started demanding reduced emissions from the agriculture industry yet, an industry representing 15% of GHG emissions to the country, despite having set ambitious goals for reduced emissions in the near future. These ambitious goals necessarily imply sharply reduced emissions by the farmers, whose industry consists mainly of animal husbandry and meat production, resulting “in the highest GHG emissions per unit of production”(Norwegian Ministry of Climate and Environment, 2018, pp. 85).

It is striking to think that the government is incentivizing red meat production to make “Norway more self-sufficient,” yet at the moment, there does not exist a tax on such emissions even though it is apparent to any observer that emissions will have to be reduced to reach Norway’s climate goals. Hence, the Norwegian government, being aware of the few designated agricultural policy instruments, has proposed in the white paper the agricultural policy published in 2016 to set specific measures and reduce emissions. To do so, it is committed to evaluating *already existing support schemes* for climate-related measures at an individual farm level (Norwegian Ministry of Climate and Environment, 2018). What does this mean for the future of farmers who are currently invested in increasing their meat production?

Such a situation has caused uncertainty with small farm owners around the country, whose discontent was shown by interviews conducted for this thesis and possibly being a part of the protests during the first days of May 2021. One of the farmers’ main concerns; their voices not being heard in such a transition.

4.5 Transition

Transitions are identified as the gradual change society endures from generation to generation. Although the achievement of such lies primarily in society’s evolution and development, it can not be accomplished without governmental structural management support. The management that this last brings must identify the clash between long-term ambition and short-term concerns. Without proper management, a cohesive and consistent public policy can not occur (Rotmans, Kemp & Van asselt, 2001).

As Rotman & et al. mention in their 2001 article *More evolution than revolution: transition management in public policy*, “The concept of transition has its roots in biology and population dynamics.” Such dynamics are not uniform and can be affected by the interplay and co-evolution of different fields, them being: economically, institutional, cultural, ecological, and behavioral. Therefore it can be understood that transitions are envisioned as multi-dimensional, and changes made within each field must be addressed and taken into consideration for a successful transition to take place.

The figure below (Figure 7) expounds on the four different stages of transition endures. They are identified as:

1) Predevelopment: Where the current situation shows no visible changes.
2) Take-off: A process of change is set into motion
3) Breakthrough: Changes start to transpire in every field, economically, institutional, cultural, ecological, and behavioral. A collective learning process takes place.
4) Stabilization: A new dynamic equilibrium is reached.

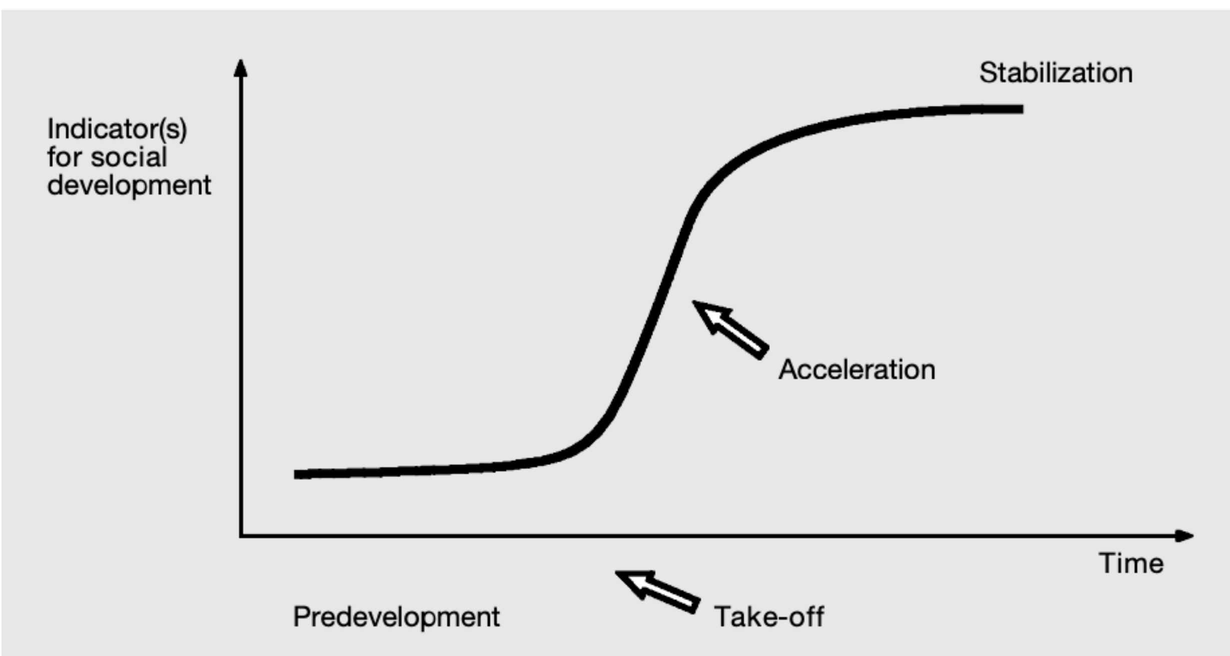

Figure 7: The four phases of transition (Rotmans, Kemp & Van asselt, 2001, pp.3)

One must also take into account that the development of every field is relative. The advances of such do not occur at the same time, and their pace can undergo periods of both slow and fast growth, where unexpected events must not be set aside, due to the impact it can and will provoke on them: for instance, accidents, economic crisis, war or oil crisis. The time-lapse such effects evoke during the transition in every domain can differ. Economic changes are abrupt, meaning that they can be "usually determined by the lifespan of capital goods," unlike cultural and environmental, where their development is slower. In contrast, institutional and technological are in between (Rotmans et al., 2001).

As Rotmas et al. further explain, these changes are also being endured within a mico, meso, and macro-level.

- The micro-level envisioned an individual approach, them being understood as environmental movements, individual actors, and companies.
- Meso: Entailing the communities and organizations.
- Macro: Encompassing the conglomerates of institutions and organizations.

These levels' dynamics are similar to those described above within the multi-level perspective approach, where actors are already identified inside the social-technical niches, social-technical regimes, and social-technical landscape.

Such reasoning does not imply that niches (individual actors) are not relevant enough to propose a transition. On the contrary, as long as the micro-level continues to be stimulated by the interplay of the other levels, technological and political advances can occur. This development can generate a destabilization of the regime that eventually helps launch the niche as a new regime. Nevertheless, for it to happen, adjustments within other domains take place for a "transition process to be expedited." Such changes will only occur if proper management of the transition is put into action. (Rotmans et al., 2001).

To further explain the said process, *Figure 8* visually expounds on the interplay of such interaction.

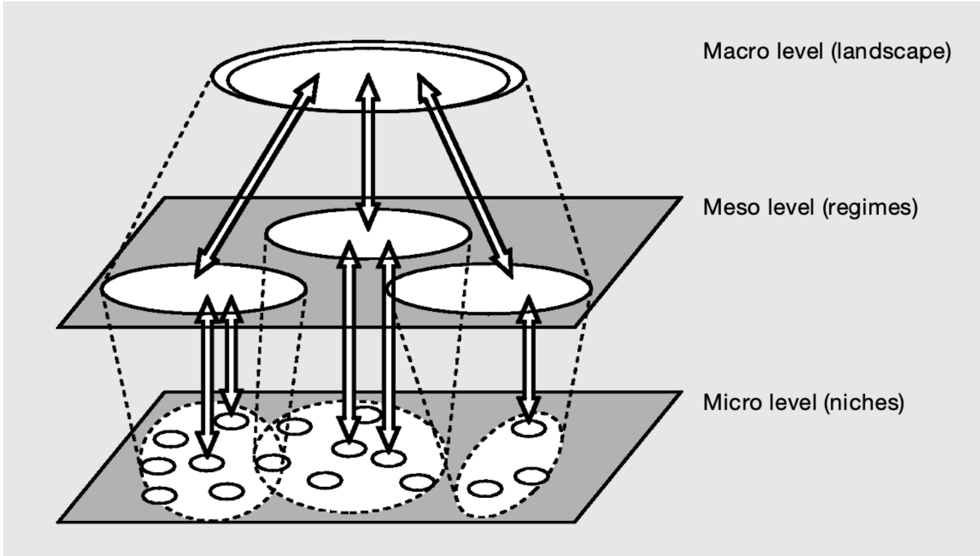

Figure 8. The multi-level perspective. Geels and Kemp, as cited by Rotmans et al., 2001

Based on what has been addressed as a transition in this section and concerning biogas in Jæren, it can be further explained, according to *Figure 8*. Farmers can be envisioned as the micro-level (niches), trying to make themselves useful through the biogas development of the area, but most importantly, they are the solid ground that will allow the other levels to further develop. Therefore immediate contact exists between them and the various organizations (Meso level), among them the Norwegian Farmers Association willing to speed the development of biogas by being the intermediators between the farmers and the ministry of agriculture (Macro level). Actions created within one level will therefore affect the others, directly or indirectly, but such interactions will help re-examine the management of the transition.

4.5.1 Transition Management

At the beginning of the century, The fourth Dutch National Environmental Policy Plan introduced transition management as official government policy (Loorbach & Rotmans, 2009). Dutch scientists dwelled on the necessities to develop a framework that could further expedite a sustainable transition. To do so, the process was constructed along with policymakers and social actors through a "searching, learning and experimenting process" (Van den Bosch, 2010, pp.19).

The transition management approach emerged from the necessity to address complex societal problems and evaluate how they are carried throughout a governance context. In recent years its implementation has facilitated energy transitions assessment. Transition Management encompasses scientific research of historical, ecological, and modeling combined with sociology, politics, and governance studies. “Because of the focus on integrated sustainability problems and the applied nature of transition research, the natural interaction between science and policy has led to a continuous co-evolution… practice of transition management” (Loorbach & Rotmans, 2009).

In general, transition management implementation helps assess future uncertainties that might occur within different scenarios by following a set of steps that will help evaluate the development of the transition. It analyses the knowledge and technological advances that enhance improvements to its relevant actors. In addition, it creates “specific tasks for the government” intending to repair brokering services. The invention of the transition management framework had the purpose of encouraging the generation of social movements and networks within the different fields. Its development helps generate pressure on the political and market arena, aspiring to protect the goals of the transition process (Loorbach & Rotmans, 2010). Transition management commitment goes as far as revising an existing system with the target of reinforcing it, for it to be improved for the greater good of the transition, or creating a new one that will be better suited for every actor.

Transition management is committed to improving existing systems, thus evaluating if the improvements made to the existing system can be such that it drives the desired transition. Otherwise, it will be forced to create new systems that correspond to a better transition, considering how beneficial it must be for the other actors with the different fields. “It is about working towards a transition that offers collective benefits in an open, exploratory manner” (Rotmas et al., 2001). It is necessary to acknowledge that the evaluation of such can not take part only within the scientific hemisphere. Since a transition is very much to occur within a societal level, society must not be put to the side when making such changes.

"Theoretically, the concept of transition management is grounded in two scientific disciplines: complex systems science and research on new forms of governance and inducing new concepts from complex systems theory and new forms of governance and inducing new concepts and practical guidelines from case studies, a practical management framework was developed" (Rotmans and Loorbach, 2001, Loorbach, 2002, Loorbach and Rotmans, 2006 as cited by Van den Bosch, 2016, pp.41).

For a visual understanding of how TM is conformed and the interplay such has with one another, *Figure 9*. addresses the main four activity clusters.

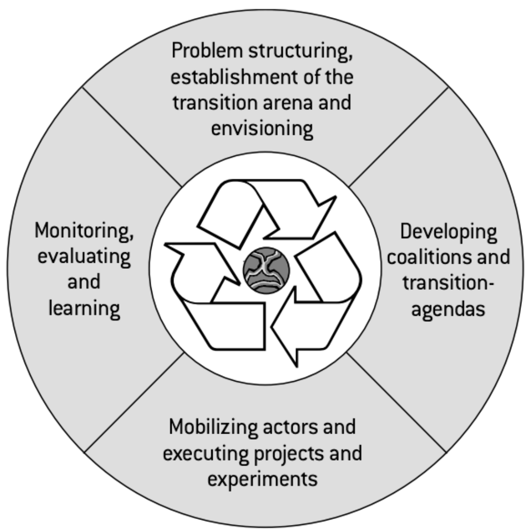

Figure 9. The transition management cycle (Rotmans and Loorbach, 2006, Loorback, 2007, Van den Bosch, 2016, pp. 45).

Loorbach reiterates that the interaction of the clusters does not necessarily have a sequence since they can occur in parallel or randomly. A depiction that has been discussed with the MLP theory structured towards a sustainable transition, which encompasses the conscious strategic pathway. "TM conceptualizes socio-technical transitions as co-evolutionary processes were landscape (macro-setting), regimes (meso-dominant practices) and niches (micro-spaces for innovation and experimentation)" (Kranjc, 2018).

To inquire on the transition of biogas production in Jæren from the MLP, it must be understood that changes being made within the agricultural industry can affect yet help reanalyze the existing socio-technical landscape in Jæren. Acknowledging the potential of the farmers within the transition, the opportunities and weaknesses that the spatial planning provides, and how willing private companies are to incentivize the production of biogas in Jæren can generate awareness of the importance of the technology play for both economic and climate purposes in the area. The interplay of such factors can help reinforce each other.

"The basic steering philosophy underlying transition management is that of anticipation and adaptation, starting from a macro-vision on sustainability, building upon bottom-up (micro) initiatives, while in the meantime influencing the meso-regime." (Loorbach & Rotmans, 2006, pp.10).

5. Research Strategy

The research strategy chosen within this research was based on the inductive and abductive research strategy. The literature review allowed a better understanding of biogas' technological aspect and the current situation concerning the said process regarding the Jæren area and its population. This phase of the study was conducted through 21 interviews, led to small farm owners in the towns of Nærbø, Varhaug, and Vigrestad, a part of Hå municipality, communities with a proliferant agro-industry.

5.1 Interview style

From their 2011 article, Sandy and Dumay describe three different types of theoretical perspectives on the research interview as a method. The first is the neo-positivist approach, which concerns studying the facts, and the second the romanticist approach that concerns studying the meaning. Finally, we have localism, being more interested in exploring the purpose of the research topic for the person interviewed. The localist perspective also emphasizes understanding the interview in its social context. The research conducted in this paper will draw on insights from both the neo-positivist and the localist perspectives. With both these perspectives in mind, the researcher attempts to gather specific facts needed and understand what the subject of biogas in Jæren means to the local small farm owners interviewed (Sandy & Dumay, 2011).

5.2 Inductive inference

Within "inference," there are three different types of approaches; abduction, deduction, and induction.

Inductive inference claims that after several observations within an individual phenomenon, one can conclude that these can be generalized when analyzed on a larger scale.

According to Berth Danemark's book, inductive inference declares that the conclusion does not follow from the premise; instead, the conclusion adds further knowledge to the premise. "We start from something known and given and draw conclusions which reach beyond this." (Danemark et al., 2002, pp.232). Danemark also claims that if the general conclusion were to be valid, it could also be used to predict events that have not arisen yet.

Therefore, the implementation of the inductive inference approach will be beneficial regarding this research. When analyzing the utilization and production of biogas in existing farms both out- and inside Rogaland, it will lead to a better comprehension of the forecast that this technology represents for the Jæren area. Therefore it will allow this study to ponder more concrete recommendations for future biogas developments, not specifically technological but on a social emphasis.

5.3 Abductive

When understanding inference, it is not sufficient to base the gathered research on statistical data. Abductive inference comprehends that there are multiple factors, both implicit and explicit, within logic that can shape the conclusion of the premise.

In its 2011 article, Douven explains how abduction differs from induction when explaining "it violates *monotonicity*, meaning that it may be possible to infer abductively certain conclusions from a *subset* of a set *S* of premises that cannot be inferred abductively from *S* as a whole." Douven also mentions how philosophers and psychologists acknowledge the use of abduction as an interpretative process in human's daily life, to the point that it goes unnoticed (Douven, 2011).

For the purpose of this research, it was determined that the use of the abduction strategy would be necessary in order to have a better understanding of the current situation in which the topic of biogas stands today in the Jæren area. The fact that utilization of the abduction strategy can be beneficial in giving access to an interpretative process within a larger context without leaving aside the inconvenience that the abduction strategy might play regarding the lack of validity it can bring is also taken into account.

6. Research Method

This thesis aims to understand the different factors that might hold back or push forward the production of Biogas in the region of Jæren as a way to minimize the CO_2 emissions throughout the agricultural field and as a potential solution to managing manure waste in the area. Therefore, the research is based on a qualitative research method, where the literature review was based on different articles, books, and Norwegian governmental publications within the grounds of biogas and agriculture in the Jæren region. In addition, a quantitative research method was also conducted to comprehend the farmer's views regarding Biogas production, how willing they will be to invest in the technology and draw an estimate of the possible cost modifications.

For this essay, it was decided to limit the viable Biogas production to the region, particularly Vigrestad, Varhaug, and Nærbø, better known as Sør Jæren. Furthermore, this research has set its interest specifically on small farm owners due to the amount of agricultural production this small area represents in relation to the entire nation of Norway.

6.1 Quantitative

Quantitative data is an essential tool within the research method. It provides a numerical understanding of the results found during the investigation. Before this is put to use, it is crucial that the research strategy, method, and theory are well examined and established before the research begins. “Quantitative data is usually produced by coding some other data, which is reduced to a number by stripping off the context and removing content from it” (Halfpenny 1996 pp.5 as cited by Blaikie & Priest pp.209). The importance of the Quantitative method lies in its highly structured nature. It helps convert the obtained word data and gets it through a coding process to provide a numerical result. This method is often used by researchers that prefer more organized and predictable data.

In their third edition book “Design social research,” Blaikie & Priest identify four categories within the quantitative methods of analysis:

1. <u>Univariate descriptive method:</u> It emphasizes single variables, helps to summarize the characteristics of the data, and finds patterns in it.
2. <u>Bivariate descriptive method</u> is used to establish the degree to which two variables co-vary; it analyses how one variable can compare or influence another.
3. <u>Explanatory analysis:</u> It identifies the influences that variables can play on a dependent variable, aiming to demonstrate causation.
4. <u>Inferential analysis:</u> It makes estimates of population characteristics from statistics. It can also be used to examine relationships or differences within a sample other than by chance (Blaikie & Priest, 2019).

Regarding this research, the quantitative method was used to provide answers to the research questions and provide a broader overview of biogas technology in Jæren in terms of how counterproductive or productive it could be to the small farm owners of South Jæren. More so, analyzing the general perspective, the small farm owners population of the towns of Vigestad, Varghaug and Nærbø have respect for biogas.

6.2 Qualitative

Data collected at the beginning of a social science research project usually starts as qualitative. In contrast to quantitative data, qualitative data tends to be implemented by researchers with a bit of notion of the subject to be studied in terms of how to begin, proceed, or what to expect from the research. Qualitative methods tend to demand an extended amount of time in the field, not to mention that the researcher's involvement is crucial to gain as much information from all the personal involvement that the field entails. Therefore many researchers might tend to go "native" in order to have a better understanding and absorption on the field. This procedure allows the researcher to take opportunities as they occur. Although it might be possible that the research cannot go completely native, it is recommended to keep a subjective approach during the data generation.

"We can regard all of the information which we acquire about the world as qualitative, and the see that under some circumstances we can use this information to create a particular kind of data, to which the properties of number can be applied" (Turnerner 1994:195 as cited by Blaikie & Priest 2019 pp.209).

This study understands that it is fundamental to inspect the farms located within the area of Jæren in order to comprehend their process and capability regarding Biogas Production. Without question, this knowledge will only be facilitated to the researcher by visitations and the researcher's involvement within the field. Interviews, recordings, and observations will also be taken into account to develop the research further.

7. Data Collection

The amount of time expected the research had while the data collection was carried took a maximum period of 3 months. It was intended that the process took place during the course of January and February. However, due to weather conditions, the agriculture industry found themselves with an extra load of work. Interviews were then carried out in the first weeks of April. It is recognized that this part of the research played an essential role in discovering results while conducting interviews or researching sources. Therefore the importance of this lapse was necessary as it influenced the outcome. As part of primary data collection, visits to the different biogas sites in the area were carried out to observe the process from beginning to end and the conduction of interviews to the farmers and the people in charge of the execution. Not only did the interviews help bring a more comprehensive picture of the operation, but it helped validate yet modify the questionnaire, previously built based on the literature review.

7.1 Data reduction and analysis

Data reduction is an important step in the research process. It is here that raw data is being gathered and turned into something useful that can be analyzed (Blaikie & Priest, 2019). This research had envisioned implementing the software Nvivo due to the aid it provides through coding for qualitative researchers. Nvivo will help organize, code, and help to analyze the data collected (UIO, 2017). Thus, this thesis understands that the preciseness Nvivo could have provided to the research was not implemented. As previously explained, weather conditions had impacted the farmer's routines, so their working hours had been extended. It was foreseen to have more extended conversations with the farmers while running the interviews; since the time-lapse was shortened, answers were as well. In this sense, qualitative data was simplified, and the program Excel was used to quantify the data and visualize the charts provided in section *9. Results*.

This is important when analyzing and inferring information from the qualitative data, transforming it into categories. This will be useful for this thesis as the qualitative methods that will be used, like unstructured or semi-structured interviews, will be helpful to create categories to make the analysis possible and generate theory from it.

This research focuses on interviewing two groups in this transition: Sample 1, i.e., conformed by the executives of the companies previously mentioned in *Section 2.6 Actors at play*, to be more precise, the people in charge of guiding the project's transition. Sample 2, which includes twenty one small farm owners located in Varhaug, Nærbø, and Vigrestad. Although both interviews were completed and ran to both samples, it should be noted that the information provided by Sample 1 was not used. The research discerned the answer provided and concluded that the information provided did not hold relevant facts that had not been already provided by the literary review previously collected. Therefore this thesis will not be analyzing results provided from Sample 1 directly.

8. Limitations of the Study

Certain limitations to the study need to be addressed forehanded to not draw conclusions with certainty that might not be justified. Therefore, one of the limitations of this study is regarding validity.

Since the farmers to be interviewed constitute only a small part of the total sample of farmers in Jæren, this study understands it could be difficult to generalize the results based only on a qualitative method, then what a quantitative method can provide, as it could be to give a questionnaire to each of the farmers in the area.

Therefore it should be noted that this study will only be focused on a specific region in Norway, that being South Jæren. One of the reasons why the scope of this study is limited to Jærens parameters is since the interviews to be conducted in the area will allow the researcher to get a deeper perspective and understanding of what the local context is within the region; therefore, it will be difficult to generalize such results to the entirety of Norway as the local context of the different areas would be different, but that is less of a case the researcher tries to generalize the findings to South Jæren.

Another limitation of the study is related to the uncertainty around certain variables, especially cost-related variables, such as transportation cost, equipment cost, manure handling cost-related problems, or uncertainties within the equipment, as mentioned previously in the literature review. These factors could possibly change, altering the farmer's opinions, which might lead to inconsistent findings if similar research were to be conducted within a specific time period. In addition, these variables could change quite rapidly.

Furthermore, this research understands that when conducting a quality research method, there is another aspect that can be counterproductive to the validity of the study. Blaikie (2019) describes the *internal validity*, meaning that people tend to behave differently than usual in ordinary situations when an experiment is being conducted; therefore, one must be careful when generalizing on a bigger scale.

Therefore, the utilization of combined research methods will be implemented through the explanatory procedure. As Blaikie (2019) explains, a quantitative phase provides results that need to be defined and could be addressed/presented at the hand of the qualitative method. *"Mixed methods can come into play, where research is viewed as occurring in stages, perhaps using different methods at each stage and involving both theory generation and testing" (Blaikie, 2019, pp.222).* This phase aims to get a better sense of the collected data to double-check if the instruments are measuring what they were intended to be measured so that the reliability and validity of the research will not be compromised.

9. Results

As previously mentioned, to evaluate the level where the transition stands currently, it was vital to fact check the farms located in the communities of Nærbø, Varhaug, and Vigrestad in regards to the biogas production of the area.

This section centers on analyzing the results given from the conducted interviews run to the farms of the area; seven farms that focus on the animal husbandry business per town, to be precise, for 21 farms. It must be noted that the people involved had no connection to the interviewer, nor a third entity provided their contacts. The farms were selected arbitrarily.

To help understand the visuals this section provides, it should be noted that the results obtained in total, collected from the three towns mentioned previously, are located below every question. Thus, in turn, each town has been represented by its part in a separate table below the total results.

9.1. How long have you been a cattle farm owner?

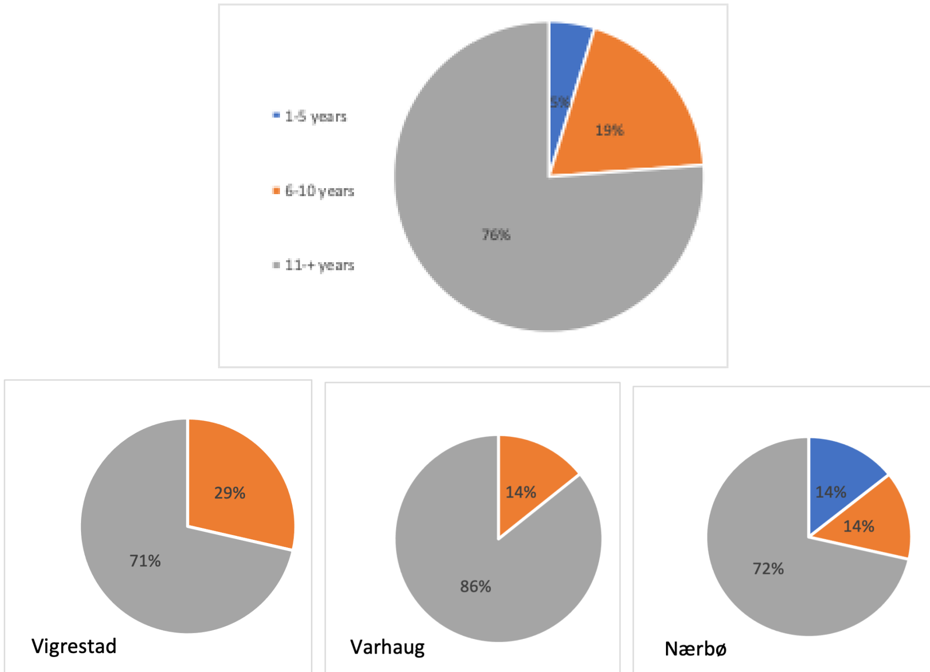

Figure 10: How long have you been a cattle farm owner?

For matters of this research, it was decided that results coming from this question will help discern the working trajectory of the farmers, how involved they are in agricultural practices and regulations.

The results projected from the charts above demonstrate that the great majority of the farms interviewed have been in the animal husbandry business for longer than a decade, representing 76% of the total sample. It shows that most farmers have gone through an extended period where they have been aware of what maintenance and production entail. Although 5% expound on being relatively new as farm owners do not imply that they have not been involved in the business before, the same explanation goes for the remaining 19%. Farmers elucidate that they were relatively new farm owners since they had inherited the farm from family members, most of them being retired parents.

9.2. Is this a business that you are sure of or would like to continue from family to family?

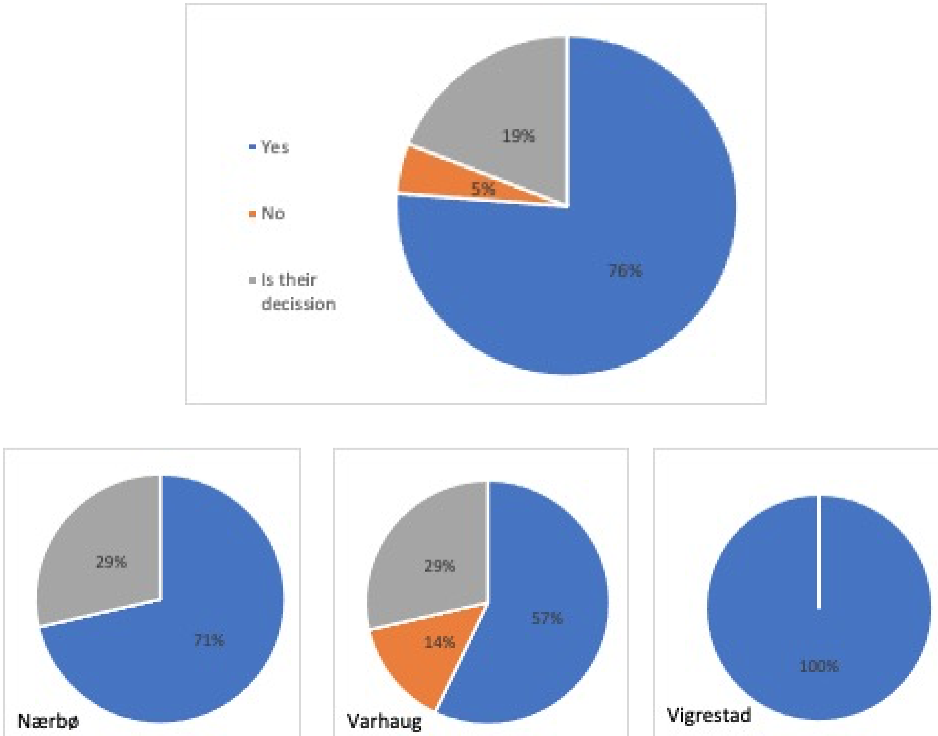

Figure 11: Is this a business that you are sure or would like to continue from family to family?

As one can deduct from the 76% of the sample, the great majority of the farmers have high aspirations as their farms legacy to be continued by other family members; in most cases, their children. Even though 19% mention that such a decision could not be imposed but instead made by their relatives, it was still noted that it would be of their liking if the decision were to continue with the farm. The remaining 5% who mention not being interested in holding the farm was collected from Varhaug. As explained by the owner, it was more convenient for him to sell his property than maintain it; due to the property being old, most of its gains were directed to maintenance and reparation, signifying economic losses.

9.3. How often does your farm need maintenance?

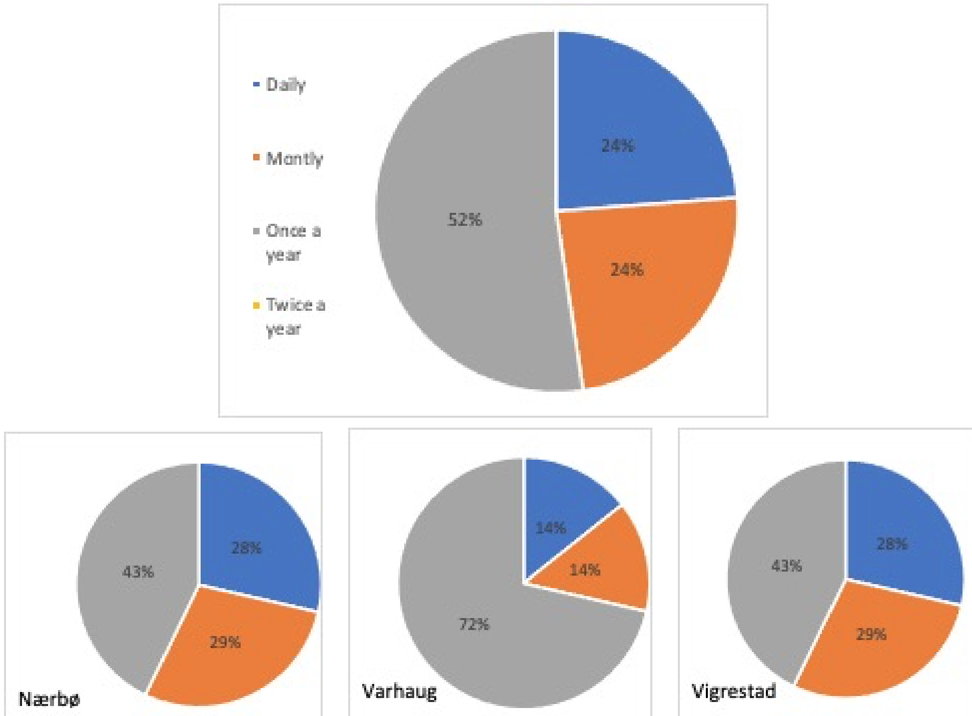

Figure 12: How often does your farm need maintenance?

Inquiring on the existing cost the farmers have to deal with on a daily basis will facilitate a level of understanding as to whether possible investments entailing biogas technology could be a viable factor.

Maintenance is an important decision factor for the farmers. The total sample mentioned that the production involves constant cleaning and supervision during the day. From this approach, 52% stressed that more significant improvements usually happen once a year; since it entails a significant economic investment, the farmers usually decide to divide the total restoration into sections to reduce cost and level their income during the year. Others expound that it was more effective to repair their barn monthly as it was easier to set a specific quota within their monthly budget. The remaining 24% clarify that although they have a fixed monthly budget, it was inevitable to resort to maintenance expenses during the day; from an extra helper wage for the day, pipes need to be reassembled, electricity bulbs, and so forth.

9.4. Are you a member of the farmers' association? If so, which one?

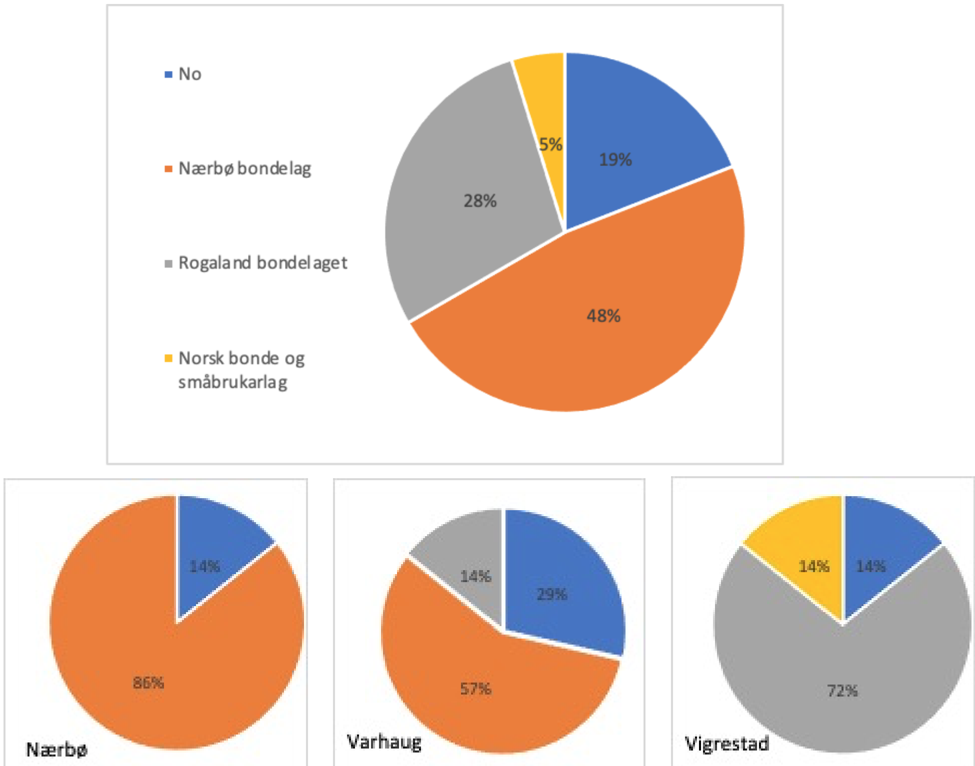

Figure 13: Are you a member of the farmers association? If so, which one?

Whether the farmers are part of a union or not will help explore how beneficial their alliance is for both of the entities within the transition in terms of process organization structure.

In regards to this question, 48% mention how loyal they were to Nærbø bondelag, even the 57% of the farmers interviewed in Varhaug answer to be part of Nærbø bondelag. To be clear, this sample was collected from the border between Varhaug and Nærbø. Even Rogaland bondelag is known to be the director for the region where Nærbø, Vigrestad, and Varhaug bondelag are branches of the association, 28% answer to be specifically from Rogaland bondelag and denying mentioning being part of the branch designated to their town. Norsk bonde og småbrukarlag represent 5% of the results, mostly mentioned in Vigrestad alone. A considerable percentage (19%) answered not to be part of a union and rather be independent. It was mentioned that they were interested in being part of a union; nevertheless, they decided to remain independent.

9.5. Has the association let you know or motivated you regarding biogas production?

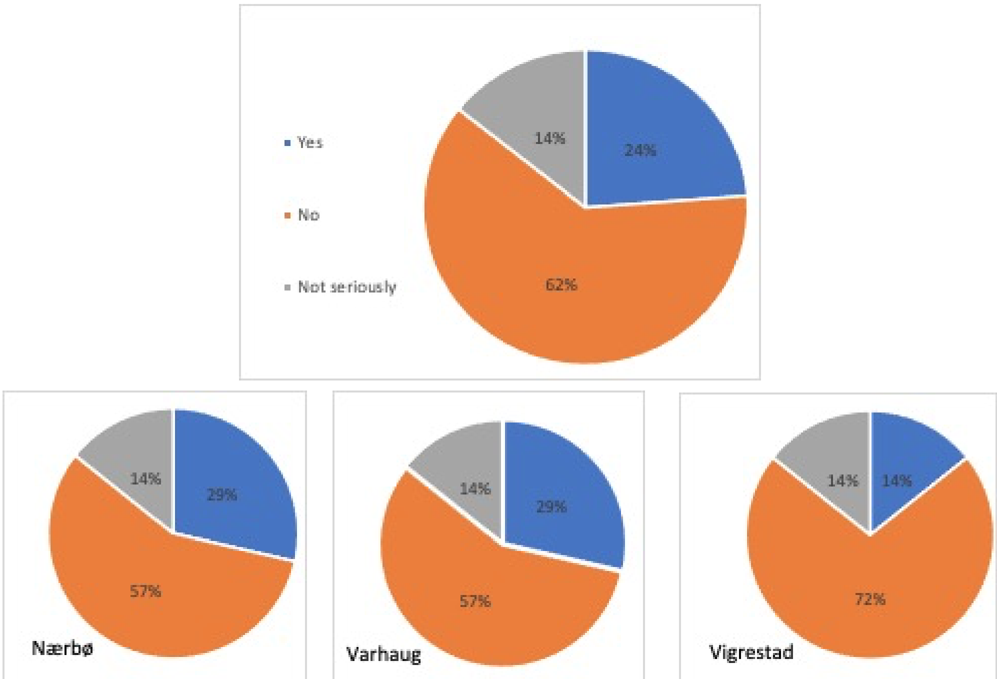

Figure 14: Has the association let you know or motivated you regarding biogas production?

Following the interest from the previous question on how unions play an essential role in developing transitions, it is important to identify whether unions have played the role of spokesman regarding biogas in technology and the advantages it can play to farmers.

Regardless of the results exposed in the question above, 81% of the farmers admitted to being part of a union. Therefore, its vital for this research to indicate how aware the population is regarding Biogas production and if the existing knowledge has been provided by the union. To this matter, 62% expressed that the union had not given information and the knowledge they had at the moment had been obtained from some articles from the newspapers.

A 14% expressed to have been giving brochures previous years, and some meetings had been held where the subject had been brought up to coalition; nonetheless, it was expressed as not being severe enough. In contrast, 24% acknowledged being provided with sufficient information from the union regarding biogas but expressed that a level of uncertainty remains.

9.6. Has a private company contacted you separately, proposing a work alliance? If so, which one?

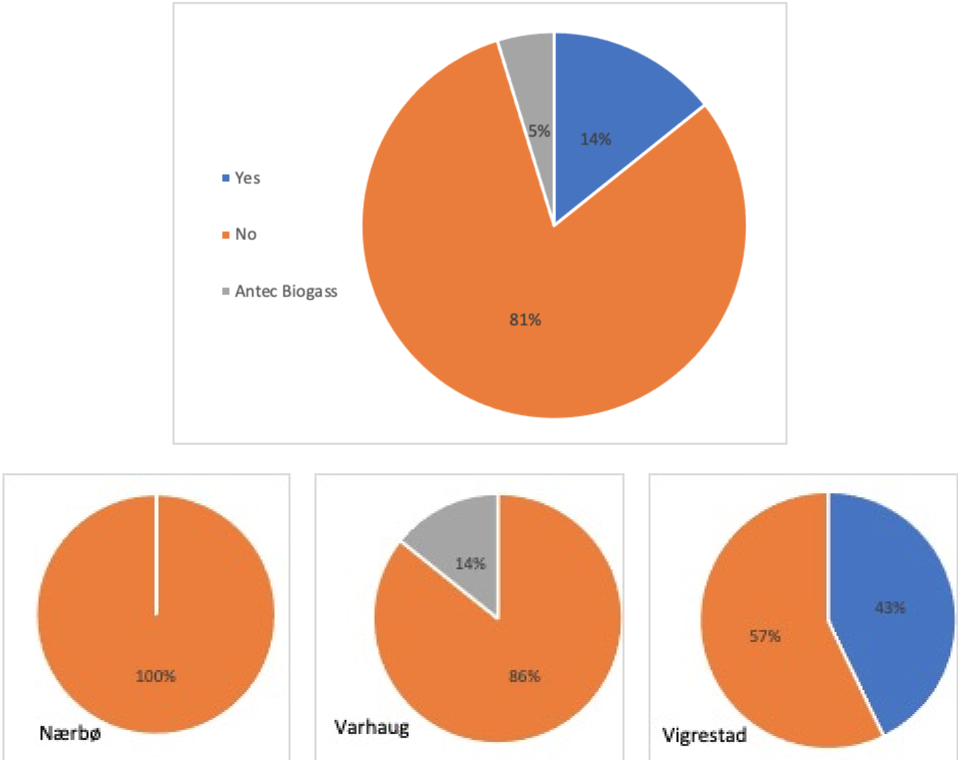

Figure 15: Has a private company contacted you separately, proposing a work Alliance? If so, Which one?

Regardless of results provided from the past questions, determining whether existing active actors promote the technology or are even communicating its existence and process is crucial in identifying the companies, unions, or governmental authorities, structuring and formulating the transition.

Results from this question were relatively straightforward. Although the towns of Varhaug, Vigrestad, and Nærbø are located near the biogas facilities expected to start production in the near future, the most significant majority responded to not being contacted by any other entity involved in biogas production. Hence the 81% outcome from this question. In turn, it can be appreciated from the results that 14% who admitted being contacted by a private entity came in total from Vigrestad. Although the farmers interviewed did not manage to specify the name of the facilities, except for Varhaug, where 5% of the sample indicated being interested in biogas. Therefore, they had taken the initiative to contact the company themselves, in this case, Antec.

9.7. Does the amount of manure collected from the cattle represent more expenses or work?

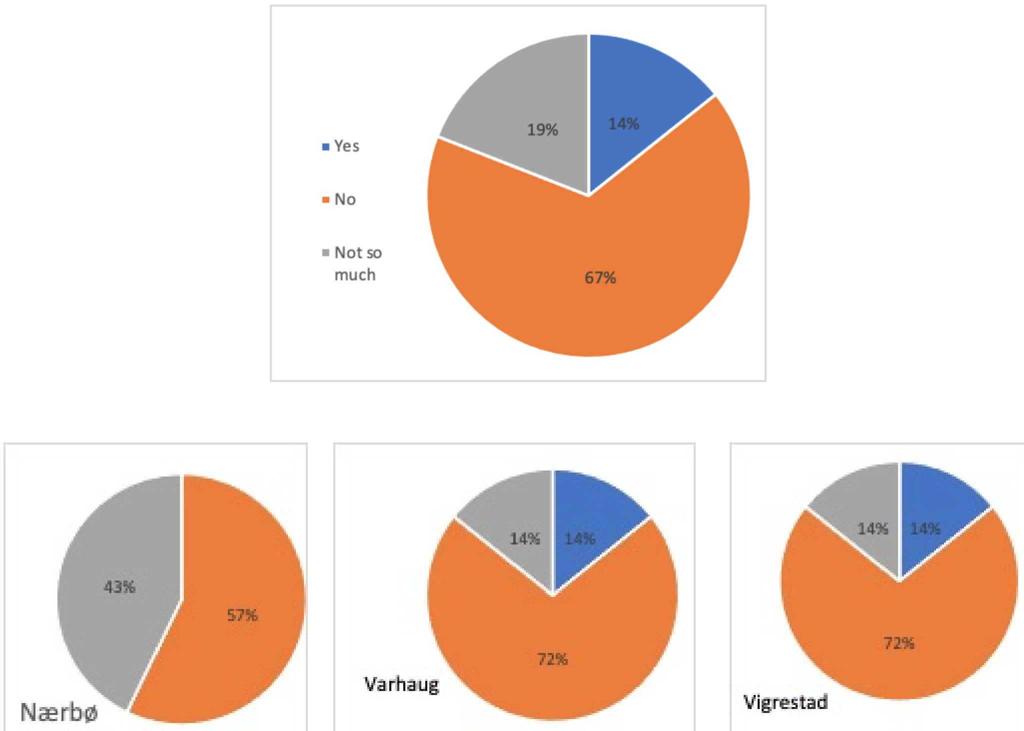

Figure 16: Does the amount of manure collected from the cattle represent more expenses or work?

Given the current debate on the new manure regulations in Norway, it was necessary to ask farmers if manure management represented a high cost to their finances. Of the total sample, 67% indicated that manure did not represent expenses since what is collected helps reduce the cost of fertilizing their fields. However, said percent of the farmers showed concern regarding the new regulations, as they could damage their budget. Thus, 19% of the sample responded "not so much," explaining that their answer lies in the maintenance and cleaning costs on the barn and spraying tanks. The small 14% who answered yes indicated that their farm holds more animals than land; a portion of the manure was shared with relatives or friends as a solution; to do so, a tank must be hired to do the proper transportation, which in turn elevates the cost in their budget.

9.8. How is the manure collected throughout the year?

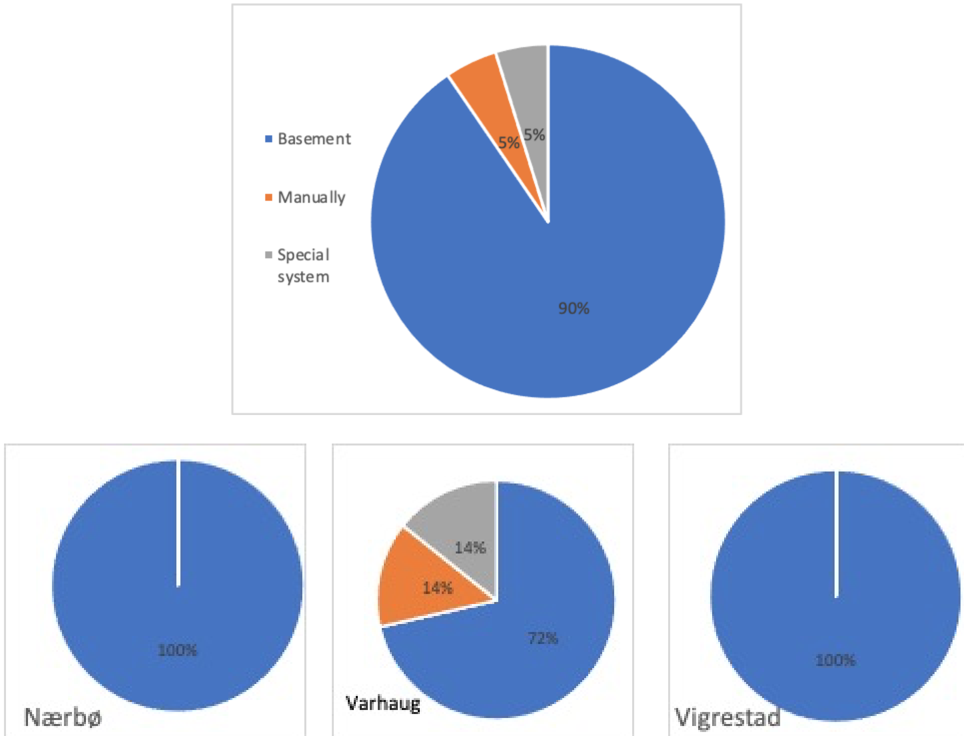

Figure 17: How is the manure collected throughout the year?

Seeking into whether installations of biogas technology could be a viable solution in the transition, results from this question will be significant for this research on determining the type of modifications needed.

As seen, 90% affirmed to recure to gather the manure through a basement method. The farmers indicated that this process facilitates the cleanness of the barn, and the collection of the manure is directly transported to the tank. On the contrary, a significant sample gathered from the town of Varhaug had different approaches. 5% indicated that being an old farm that has not been through proper maintenance, the implemented method for manure collection is still being carried with a water hose, where the pressure of the water moves the manure towards the tank pipe. Also collected from Varhaug, the remaining 5% of the total sample mentioned having an advanced method based on a separator, emphasizing their enthusiasm regarding Biogas. The farm has already made advances on contacting a private company.

9.9. What does your farm do with the manure not used throughout the year?

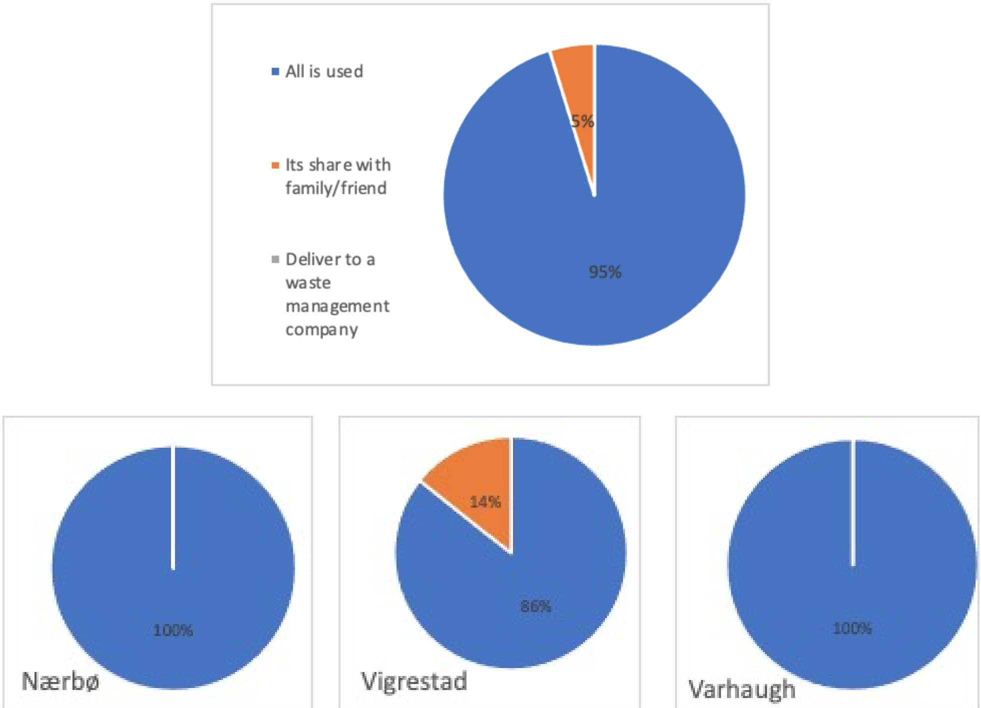

Figure 18: What does your farm do with the manure not used throughout the year?

The research finds it valuable to inquire into the existent practices farmers resort to from handling the manure. It is critical to identify if the potential of the manure is being used to the maximum and if there are existing actors that are of interest for future planning regarding the development of biogas in the area, as a way to examine more solid solutions both for the farmers and possible biogas production of the area that will help reduce cost for the farmers while boosting biogas production. To this extent, without hesitation, 95% described utilizing the entire manure of the farm during the year, and in some cases, even buying extra fertilizer was necessary. The sample also mentioned that new regulations bring an atmosphere of commotion around the farmers since it is believed it will mean stretching their budget based on the purchase of fertilizer. In contrast, 5% indicated that due to being owners of a small extension farm, it was necessary to share twice a year a percentage of the manure with family members or near farm neighbors.

9.10. How often do new regulations for manure control take place?

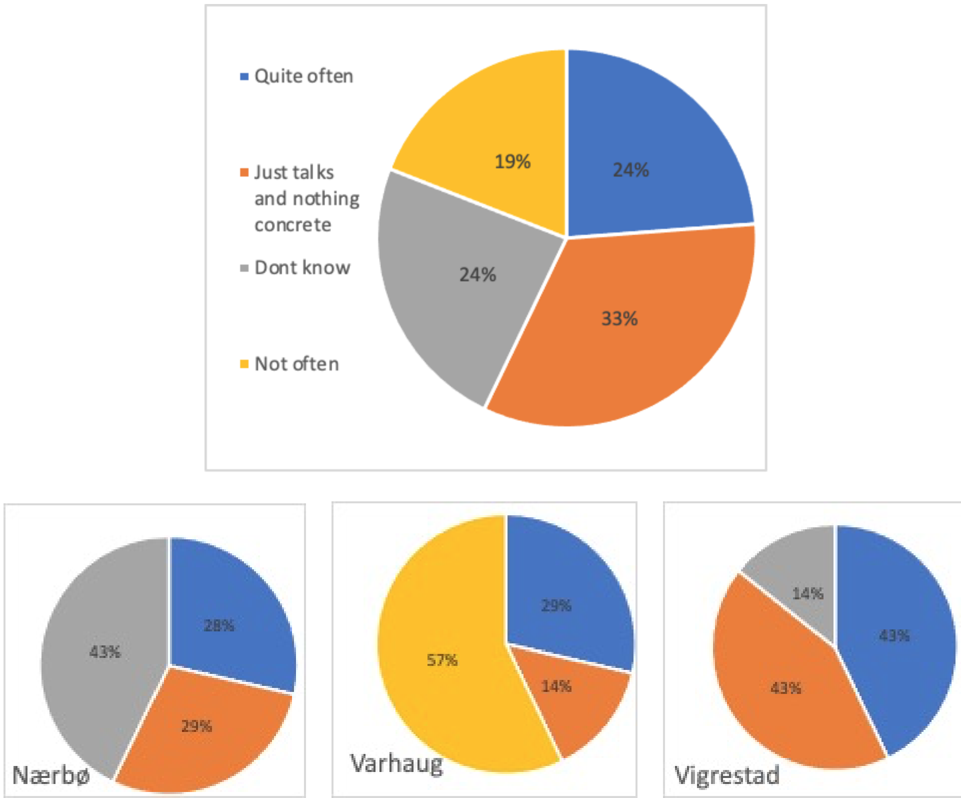

Figure 19: How often do new regulations for manure control take place?

The political approach from the farmers' perspective was taken into account. If farmers felt the government is demanding more from them than what they could do, this will be demonstrated by the provided results from this question. Beyond determining the lapse of time, new regulations are put into action to analyze if there was a level of uncertainty or exasperation towards the political decision-making.

As shown, 33% of the sample expressed not being capable of identifying if new regulations have been put in motion or not, since they considered that it had been primarily talks and nothing concrete. The level of uncertainty was reinforced by the 24% not being able to make estimations (Don't know). In addition, another 24% indicated that it felt regulations had been made quite often that it was hard for them to keep track. The remaining 19% reveal that although the atmosphere is ambivalent lately, they certify that it has not been often due to extensive talks and debates.

9.11. Is biogas a process that you could be interested in implementing for your own use?

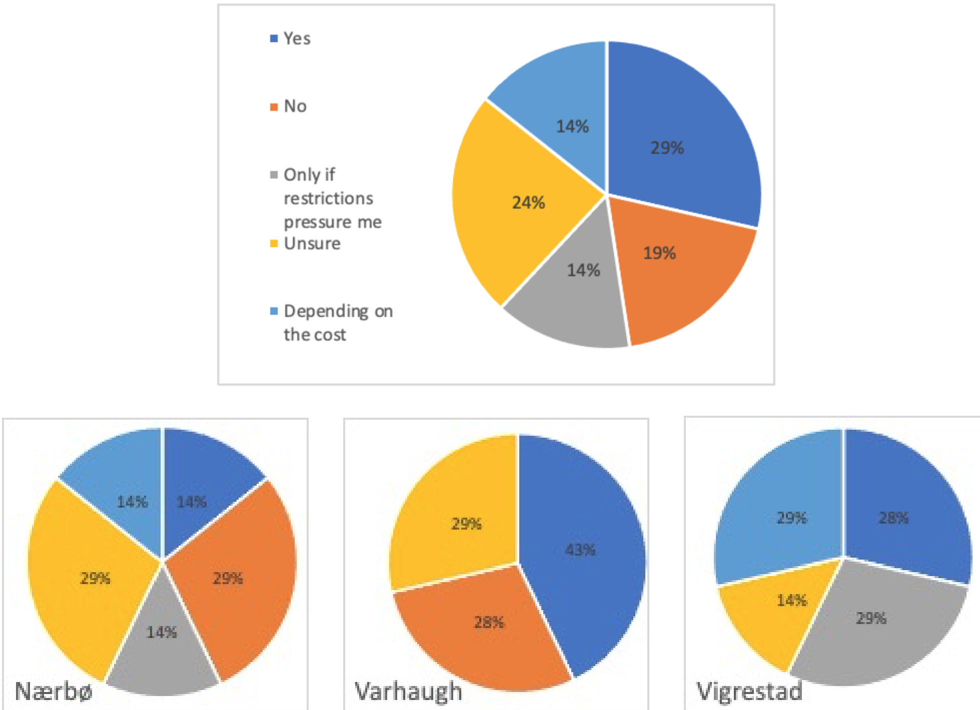

Figure 20: Is biogas a process that you could be interested in implementing for your own use?

It is crucial to understand how willing the farmers are to take part in such a transition, whether they find it necessary to prevail in the business, whereas it is a technology they find interesting as a climate change mitigator or just adding uncertainty to their profession.

To this extent, 29% seem positive, answering yes to adopt the technology. In contrast, 14% mention that the cost will be an essential factor in their decision making (Depending on the cost). A 14% seem reluctant while answering it will depend on if the new manure restrictions pressure them to do so. Results could also be linked to the 24% of the sample who answer to be unsure; lack of information, concerns regarding the cost and the amount of added work, where factors involve, either separately or on the whole. A straightforward no was responded from 19% of the sample. The interviewers neglected explanations.

9.12. What is the atmosphere between farmers around biogas?

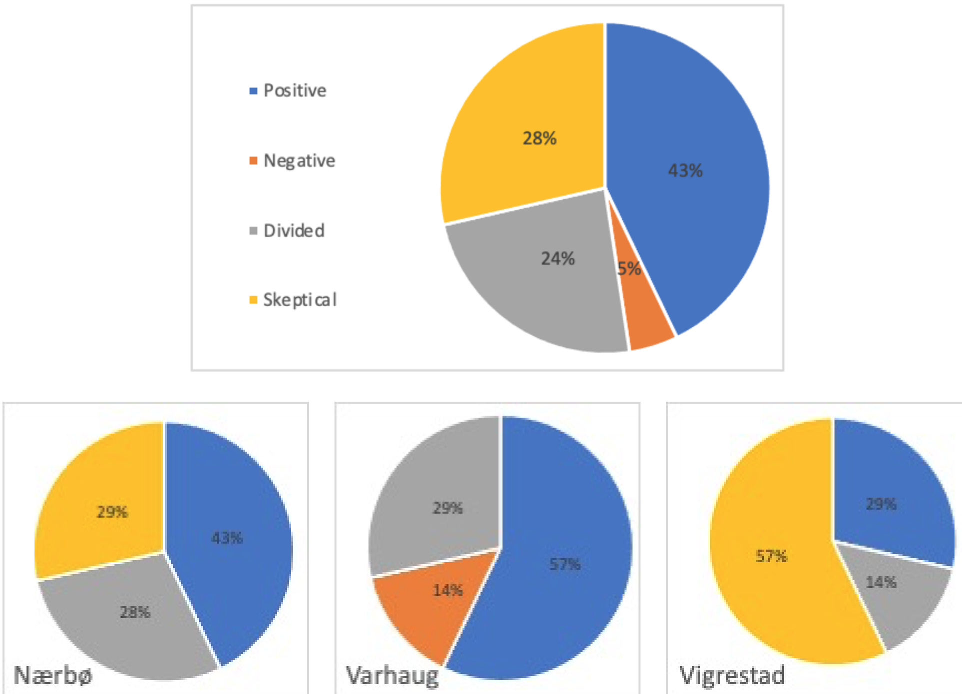

Figure 21:What is the atmosphere between farmers around biogas?

Since individual views were already collected, it was essential to identify if such answers reflected the current atmosphere from the farmers of the area, whereas the answers were influenced by it or made on their own.

The results demonstrated that 43% envision the atmosphere in the community as being positive towards biogas production. On the opposite, 28% declare the atmosphere of being suspicious, tending to fear of what such changes could imply. A 24% expressed interest in it being divided, explaining that the younger generation of farmers are more positive towards an adjustment in general and the old generation are reluctant to them, as they instead continue with their already known routine. One small 5% indicated feeling negativity towards the technology because it was felt that not enough information had not been provided.

9.13. Do you think you will be willing to implement biogas production on your farm regardless of the other acquainted farmers not being interested?

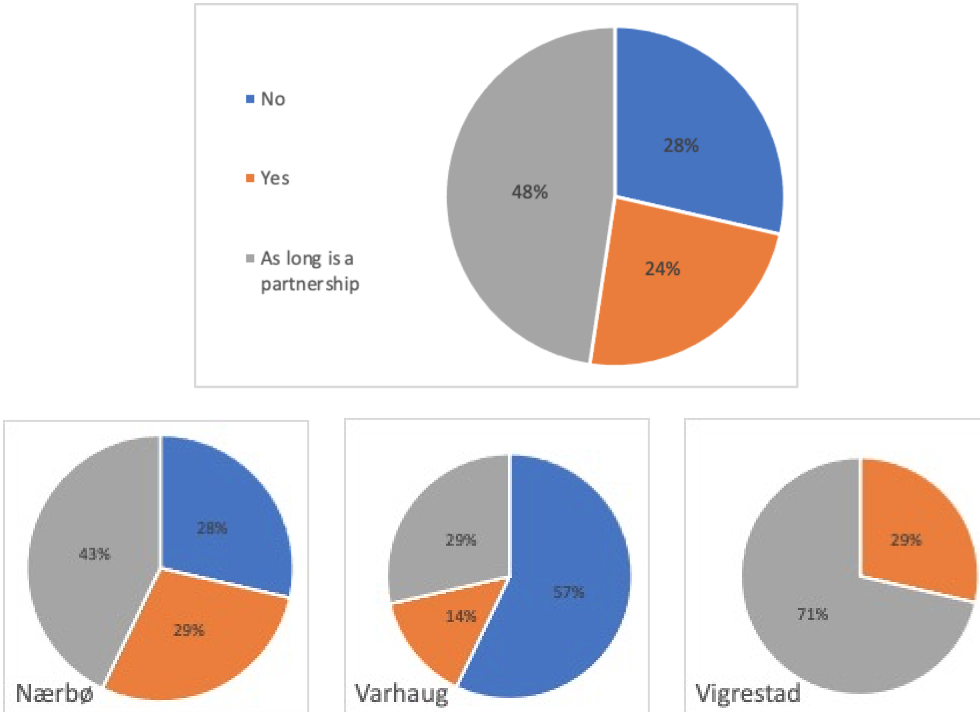

Figure 22: Do you think you will be willing to implement biogas production on your farm regardless of the other acquainted farmers not being interested?

Identifying how close farmers are to each other and if it impacts their decision-making as individuals is essential. It will help understand if future decisions will not be set back as a product of their colleagues' influence in the future.

It is significant to highlight that 24% answered yes. Thus, the farmers' decision whether they will be willing to work with biogas is their personal decision regardless of whether neighbor farmers neglect to join in. As follows, 43% declare to favor the transition so long they are offered to be partners of the companies impulsing biogas production in Jæren. If that is not a viable factor, they are not interested regardless of what the others do. On the contrary, 28% manifested that even if it could be possible to work with biogas, it was more important for them to be on good terms with their neighbor's farmers.

Based on the results presented in this section, this research will move on to the discussion: What are the crucial factors repressing or expediting this important transition to a more sustainable energy and agricultural landscape?

10. Discussion

Based on the results collected from section 9, it is essential to explore the different aspects that must be considered to assess if the transition management regarding biogas is heading towards an optimistic scenario in the area in question.

As renewable technology is needed as the most beneficial solution for the planet's harms regarding climate change, changes must be made in every sector. As previously mentioned, biogas is not a newly discovered technology; it has been part of human development in different forms. However, in recent years its implementation has been diverted towards the creation of clean energy to reduce the use of fossil fuels. As discussed in the literature review, improvements within the transition can imply increasing efficiency, legislating to incentivize biogas production, creating new processes to facilitate production, determining the optimal position of plants, building partnerships to transport and process the manure, investing in companies interested in financing biogas developments in the area, and finally government subsidies and regulation.

Based on the data collected in South Jæren corresponding to the towns of Nærbø, Varhaug, and Vigrestad, this thesis can present the discussion of given results in comparison with the research questions that the research aims to address in section *3. Problem Statement* and *3.1 Research Questions.*

As previously addressed in the literature review, Jæren has an enormous potential for developing biogas in the area, hence the expressed interest from different enterprises. Since 2009 the Norwegian authorities have proposed initiatives to promote and incentivize biogas to lower methane emissions and the surplus of sulfur from livestock manure.

It could be thought that most of the farmers around the area should have been aware of the process and potential benefits that biogas represents to them and the country. Nevertheless, in the findings presented from the interviews conducted with the farmers of the area, it was shown that more than half of them had not been given information on the technicalities biogas can require from their barns, husbandry, field, economics, or even the work it would represent for them.

Previously expounded in this research, the actors playing a fundamental role in this transition are well-funded companies interested in investing in biogas in South Jæren. It so happens that the great majority currently sustain a working relationship with the farmers. This includes corporations supplying their catalog from farmers' husbandry production, enterprises working within the energy conversion sector providing the farmers' heat and energy, companies selling products for agricultural work, and unions whose primary interest is to safeguard the farmers' interests. Given the existence of these numerous actors within different fields of the chain arbitrating biogas production, it was vital to identify if there has been any interaction from the companies towards the farmers and more so how such communication has arisen. To figure such brings the question: *Has a private company contacted you separately proposing a work alliance? If so, which one?* was made. To this thesis' dismay, 81% of the total sample answered no. Such results are disquieting since many of these companies have a common interest in the livestock manure produced by the farmers, due to being the main component for biogas production. From such results, one can assume that since there has not been any significant interaction from private entities towards the farmers, the Norwegian Farmers Association could have played the part of intercommunicator. After all, the Norwegian Farmers Association, or Norges Bondelag, has been in charge of ensuring the interests of its members for over a century. Adding on the prevailing loyal relationship that remains from the farmers towards the entity, which shows from the interview results, 76% of the total sample were expressed as union members.

The research aimed to prove this hypothesis by addressing whether *the association let you know or motivated you regarding biogas production?* However, this was not the case since 81% of the farmers had not been provided with information regarding biogas development. This is despite Norges Bondelag's conjoinment magazine with other farmers' unions, where important content regarding the agricultural news is published weekly.

This is an important factor that must not be overlooked; it must be understood that participation and intake from the primary providers must be decisive for this transition to be successful. Such is the dynamic of Bioenergi Finnøy AS for over a decade; despite the economic inputs that have prevented the project from occurring, the company still maintains communication with the 26 farmers who remain willing to take part in what will be the first biogas plant in Finnøy.

Based on this evaluation, this thesis can address Research question 1. *Is biogas technology being domesticated by South Jæren farmers?* As it comes to show, farmers are not domesticated regarding biogas since they do not have the necessary knowledge on what biogas entails. This harms the development of the transition from occurring since the fundamental actors lack education, and therefore it represents a delay in the production of biogas in South Jæren. This leads to answering Research question 2. *What is the potential of biogas development in Jæren?*. As mentioned in the literature review, the vast amount of south Jæren's diverse animal husbandry asserts the enormous potential the technology can rely on, especially when considering future, more restrictive regulations regarding land and manure use, hence the interest of different companies on establishing biogas facilities in the area. Unfortunately, the potential is curtailed by the same fact as the previous question: farmers are not informed, nor do they have knowledge of what biogas production will demand from them or will entail.

Since most farmers are members of a farmers union, it would be advisable for such entities to study more suitable communication tools to spread information directly to the farmers. It will reassure the integration and incentivization of south Jæren's population on this matter, which in turn will help stimulate the farmers to take part in employment-generating technology.

The importance of taking such measures promotes satisfactory results in different scenarios, especially since most farmers see their farm being carried on by their future generations, as was shown by the results provided to question *9.2 Is this a business that you are sure or would like to continue from family to family?* More than 75% of the interviewees answered yes, regardless of the implications agriculture work entails or the economic input their farm generates annually, as was supported in question *9.3. How often does your farm need maintenance?* Moreover, question *9.7 Does the amount of manure collected from the cattle represent more expenses or work?* 3%

responded it did, presumably not considering future legislative restrictions on how much manure they are allowed to use on their land. Based on these results, research question 3. *What will the advantages be regarding the production of biogas in Jæren and the challenges it might face in Jæren and its farm owners?* It can be resolved as the determination of the farmers to persist as agriculture producers remain. This suggests that investments made to biogas production in Jæren will not be in vain; the technology can be introduced, and production can continue by the hand of future generations. Reducing costs in energy conversion, using biowaste will make the most from the nutrients in the manure for fertilization of fields as well as creating clean energy.

To culminate by answering the research question *4. What will the policy implications be regarding biogas production in Jæren as a whole and individually for small farms?* Results from four questions were vital in determining the implications. The great majority, 90% of the farmers, answer that they already have installed a basement in their barns, which helps facilitate manure collection. This indicates that if adjustments were to be made as mandated from the agricultural settlement, such as renovations to create loose housing dictated from the infrastructure, manure collection must also be added. After all, concerning the answer provided in question, *9.9 What does your farm do with the manure not used throughout the year?* Where 95% of the total sample expressed utilizing all. However, it should be noted that this was before new regulations apply. A surplus will not only mean the farmers need to trust the process of collection of the manure but, more importantly, getting the biowaste in time to fertilize the fields. Good communication must also follow such regulations, as was shown from results collected in question *9.10 How often do new regulations for manure control occur?* The varying answers address a level of uncertainty leaning towards confusion. Regardless of such, it must be acknowledged once more that the determination that the farmers express in being included in new economic gains as well of feeling part of the greener change as was pointed out in question *9.13 Do you think you be willing to implement biogas production on your farm regardless of the other acquainted farmers not being interested?* 28% answered directly that they would not be interested in having any discrepancies with their neighbors, reinforcing the loyalty that farmers present once good relations are established. Thus this might not overcome the sense of responsibility regarding environmental matters, since the rest answered being willing to take part in the transition, where 24% made it clear that as long as they are in a partnership. This is a strong indication of the economic status that the farmers find themselves in at the moment.

11. Conclusion

The purpose of this study was to increase the understanding of how the current state of a transition to expanded biogas production by local farmers in south Jæren could stimulate the local economy and reduce Norway’s greenhouse gas emissions. In order to do so, the empirical data collected in the study, in conjunction with data about current and future manure regulations, biogas processes, and the interest shown by governmental and private entities, brought a broader view of the current state of the transition regarding biogas in Jæren.

The study has shed light on the impacts manure regulations can cause to the farmers' economy and, in turn, food production in Norway. It is vital to create a niche for emerging innovations and a willingness to invest in developing a non-existing technology in the area due to the enormous potential Jæren’s agricultural industry represents. This thesis has pointed out the advantages and struggles this transition is undergoing along the process. If this transition were to occur, it could represent advantageous changes within every step; on the micro-, macro-, and meso- levels. The micro-level being represented by the farmers of the towns of Nærbø, Vigrestad, and Varhaug, to a promising opportunity of remaining relevant for energy conversion changes, would provide a solution to the problems farmers will solve face concerning the excess of manure they are producing according to stricter new regulations. On the macro-level, these changes would contribute to the mitigation of methane emissions in Norway. Finally, on the meso-level, it would bring an economic rise for generations of farmers while protecting the region's watercourses and soil from pollution.

At the beginning of the research, it was assumed that biogas production would strictly lie within the manure regulations and how such could directly affect farmers' performance. It was thought that it would lead farmers to seek other job opportunities. In actuality, based on the collected literature review and data provided from interviews, it shed light on a different factor:

communication. The lack of information communicated in the area has led to confusion and exasperation due to no entity presenting any interest in initiating a dialogue with the farmers.

The key takeaway from the results of this thesis, and the answers to all the questions posed at the beginning, is that there needs to be better and more communication with the farmers. Second, there is a potential, a need, and a will for increased biogas production in Jæren. The potential is the large livestock and manure production. The need is both Norway's international GHG commitments and possible more stringent regulations regarding manure and land use, and the will is evidenced by multiple governmental and private actors pushing for increased biogas production. Finally, there are the farmers, who are the key to this entire landscape shift. They are the potential future of agriculture in the region, they need to be able to continue producing food and making a living, and they have a will to continue, but need to be supported by all the aforementioned actors in order to do so.

12. Recommendations

As a final note, this thesis will address some areas of inquiry as recommendations for future studies.

- The study has concluded that communications play an essential role for this transition to be successful. Therefore it is recommended that both private companies and governmental entities develop a direct approach with farmers as a method to listen to their needs and inquiries. This will not only facilitate the progress of better transition management but will develop trust between the actors.
- The research also brought light to a crucial factor for the farmers' decision making and is the lack of economic certainty. For that matter, it will be advisable to develop a more concrete plan that increases the subsidies needed not only related to biogas development but, as previously mentioned, to decrease the wage gap the farmers that currently face, evident or evidenced by the recent protests.
- As previously explained, this thesis had envisioned implementing the program Nvivo, yet it was decided that it was more suited to calculate the data using Excel to reduce the data collected. For further studies, it will be advisable to implement the program to obtain cleaner results if interviews were to be conducted. In addition, it will shed light on other uncertainties this study might have overlooked.

It is vital to comprehend that in order to achieve Norway's environmental goals, it is without question that a participatory process with the stakeholders is needed. Although it might require extra time to agree with every party, it will facilitate the greener transition involving the reduction of GHG emissions from agriculture and providing emission-free fuels.

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Appendix

10.1 Contract

Are you interested in taking part in the research project:

"Biogas in Jæren: is it really viable for small farms?"

This is an inquiry about participation in a research project where the primary purpose is to analyze the public debate within Norway's climate strategy, seeing as most of the farms in Jæren do not utilize the entire collected manure. As such, farmers will be forced to reduce their number of animals. The purpose of this thesis is to present a solution where reduction of animals should not be necessary if the manure production is put to use as an energy generator on the farm and possibly to the local communities. In this letter, we will give you information about the purpose of the project and what your participation will involve.

Purpose of the project

This master thesis' main purpose is to examine the cost uncertainty that can make small farms err on the side of caution and not make the necessary investments and the existing policies and/or subsidies. It will also examine possible scenarios that might hold back or push forward biogas production in Jæren. The main questions this research will dwell on are:

1. What is the potential of biogas development in Jæren?
2. What will the advantages be regarding the production of biogas in Jæren and the challenges it might face.
3. Could biogas be a technology that the farmers of the area will be interested in investing in?
4. What will the policy implications be regarding biogas production in Jæren as a whole and individually for small farms?

Therefore, interviews of professionals in the matter and small farm owners are necessary to gain a broader perspective of the current atmosphere regarding the technology. Names and work titles will be used to guide and back up the investigation, as long as interviewees give their consent.

Who is responsible for the research project?

As a student of Universitet i Stavanger, me, Nataly Coronado Mijangos, along with my supervisor Homam Nikpey Somehsarae.

Why are you being asked to participate?
Your participation has been requested for purposes of this research; due to the vital knowledge your input can provide to the investigation: Whether you hold a governmental position that could guide this thesis from the current or future policy state, as a leader of the biogas department in a private company or a small farm owner that will add a broader view on the technology and the position that you hold. In addition, the input of farmers considering biogas or ones who have already started implementing such solutions is relevant.

You have been contacted from the researcher's investigation, from the public domain, or, if applicable, a third-party recommendation.

What does participation involve for you?
The data collected from this interview will be sound/video recorded and categorized as either qualitative or quantitative. If necessary, some information provided by you will be quoted in the research. External information collected from the internet will be mentioned as well, such as previous articles, records, white papers, laws, and studies where your company, governmental department, or name has already been published.

Participation is voluntary
Participation in the project is voluntary. If you choose to participate, you can withdraw your consent at any time without giving a reason. All information about you will then be made anonymous. Therefore, there will be no negative consequences for you if you choose not to participate or later decide to withdraw.
The published content based on the provided information has no intention of harming your labor/industrial relations. A copy of the material will be provided if requested by you.

Your privacy – how we will store and use your personal data
We will only use your personal data for the purpose(s) specified in this information letter. We will process your personal data confidentially and following data protection legislation (the General Data Protection Regulation and Personal Data Act).

Your personal information, if necessary, will only be discussed with the supervisor of the study, a member of the faculty from Universitetet i Stavanger, which has already been mentioned in the section above. No unauthorized person will be able to access the data since your name, and contact details will be managed with a code. The names, contact details, and respective codes will be stored separately from the collected data. I will store the data on a research server, locked away/encrypted.

What will happen to your personal data at the end of the research project?
The project is scheduled to end in July. After all the information has been revised and approved, audio-visual recordings and emails will be deleted from the database.

Your rights
So long as you can be identified in the collected data, you have the right to:
- access the personal data that is being processed about you
- request that your personal data is deleted
- request that incorrect personal data about you is corrected/rectified
- receive a copy of your personal data (data portability), and
- send a complaint to the Data Protection Officer or The Norwegian Data Protection Authority regarding the processing of your personal data

What gives us the right to process your personal data?
We will process your personal data based on your consent.

Based on an agreement with Universitetet i Stavanger, NSD – The Norwegian Centre for Research Data AS has assessed that the processing of personal data in this project follows data protection legislation.

Where can I find out more?
If you have questions about the project or want to exercise your rights, contact:

- ***Universitetet i Stavanger* via**
- **Nataly Coronado Mijangos (**Researcher):

E-mail: nathalyecm8@gmail.com
Phone no. +47 46 29 95 90

- **Homam Nikpey Somehsarae** (Researcher supervisor):

E-mail: homam.nikpey@uis.no
Phone no. +47 51 83 25 34

- NSD – The Norwegian Centre for Research Data AS, by email: (personverntjenester@nsd.no) or by telephone: +47 55 58 21 17.

Yours sincerely,

Homam Nikpey Somehsarae
(Researcher/supervisor)

Nataly Coronado Mijangos
(Student)

Consent form

Consent can be given in writing (including electronically) or orally. NB! You must be able to document/demonstrate that you have given information and gained consent from project participants, i.e., from the people whose personal data you will be processing (data subjects). As a rule, we recommend written information and written consent.

- *For written consent on paper, you can use this template*
- *For written consent, which is collected electronically, you must choose a procedure that will allow you to demonstrate that you have gained explicit consent (read more on our website)*
- *If the context dictates that you should give oral information and gain oral consent (e.g., for research in oral cultures or with people who are illiterate), we recommend that you make a sound recording of the information and consent.*

If a parent/guardian will give consent on behalf of their child or someone without the capacity to consent, you must adjust this information accordingly. Remember that the name of the participant must be included.

Adjust the checkboxes in accordance with participation in your project. It is possible to use bullet points instead of checkboxes. However, if you intend to process special categories of personal data (sensitive personal data) and/or one of the last four points in the list below is applicable to your project, we recommend that you use checkboxes. This is because of the requirement of explicit consent.

I have received and understood information about the project *[insert project title]* and have been given the opportunity to ask questions. I give consent:

¨ to participate in interviews

¨ for information about me/myself to be published in a way that I can be recognized as described earlier

I give consent for my personal data to be processed until the end date of the project, approx. *July 2021*.

(Signed by participant, date)

10.2 Questionnaire: Sample 1

Date:____________________

Name: ____

Company: ____

1. How long has your company/department invested in promoting Biomethane in Jæren?

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2. What are the main attributes that make Jæren a good region for developing Biomethane?

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3. What is the atmosphere regarding Biogas in Rogaland?

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4. What is the current perception of Biogas in Jæren?

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5. Since Biogas is a perfect way to manage the current waste problem, what are small farms doing at the moment with the excess of manure they do not get to use as fertilizer? What is the current solution to that problem?

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____

6. What is your company/department vision regarding Biogas for Jæren?

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7. Is there a current economic incentive for small farmers to motivate them to join the technology?

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____

8. Will you say that Cattle and sheep farmers are more engaged with biogas than fish farmers?

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____

9. What is or will be the relationship between the small farms and your company/department?

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____
____
____

10. Could Biogas be a good contender against Hydrogen or an ally?

11. Could that be enough reason to motivate or demotivate the progress of Biomethane in Jæren?

12. In your words, what is the main obstacle preventing the progress of Biomethane in Jæren?

10.3 Questionnaire: Sample 2

Date:____________________

Name: ____

Company: ____

1. How long have you been a cattle farm owner?

2. Is this a business that you are sure or would like to continue from family to family?

3. How often does your farm need to get maintenance?

4. Are you a member of the Farmers association? If so, which one?

5. Has the association let you know or motivated you regarding Biomethane production?

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____

6. Has a private company contacted you separately, proposing a work alliance? If, so which one?

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7. Is the amount of manure collected from the cattle/sheep representing more expenses or work?

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8. How is the manure collected throughout the year?

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9. What does your farm do with the manure not used throughout the year?

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____

10. How often do new regulations for manure control take place?

11. Is Biomethane a process that you could be interested in implementing for your use?

12. What is the current atmosphere between farmers around Biogas?

13. Do you think you will be willing to implement biogas production on your farm regardless of other acquainted farmers not being interested?