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Drivers and constraints in an emerging rural biogas system: actors' perceptions from Northern Savonia

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Abstract

Background The biogas niche is usually approached from a top-down perspective, and its actors are considered a unanimous advocacy group in the national policy discourse. This setting downplays the diversity of actors and their opinions at a subnational level. In this study, ten biogas actors from the farm-level, industry, regional administration, and potential end-users in the Finnish region of Northern Savonia were interviewed. The actors' perceptions of the national and regional biogas sectors were explored.

Results The national biogas policy framework appears discontinuous, and statements regarding biogas targets are perceived as ambiguous, thus lacking credibility at a local level. The economic feasibility of rural biogas production places a strong boundary condition for the local biogas system. When moving from the national to a local level, individual actor's perception of the optimal value chain becomes highlighted. Extending the actor network beyond the regional context was deemed vital for the long-term stability of the locally emergent biogas ecosystem. As municipalities can influence both production and consumption domains, they were called to play a more active role in constructing local biogas systems.

Conclusions The results of this study provided three insights: (1) social, political, and environmental drivers influence the biogas sector in addition to techno-economic drivers; (2) drivers and constraints are perceived differently by actors in agricultural biogas production than by actors in distribution and end-use; and (3) the local biogas niche contains partly divergent perceptions of how the biogas system should be organised. Connecting actors early through joint planning and formulating case-by-case business models may help mediate any conflicts of interest.

Keywords Rural biogas system, Rural development, Active interviews, Qualitative content analysis, Finland, Case study

Background

Historically, Finland has relied on bioenergy as an integral part of its energy mix and promotes biomasses as a domestic emissions reduction solution. Biogas has been recognised as a suitable technology for Finnish conditions, with major synergies in rural development and ensuring the security of energy supply through domestic means [1]. In the Finnish media, biogas has similarly been framed mostly positively as a promising technology with great future potential [2]. Despite the emphasis given to bioenergy in national policy

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documents, the development of the biogas sector has remained relatively weak in Finland during the twenty-first century. In 2020, only 686 GWh of biogas were produced in Finland's 79 biogas plants¹ [3, 4], which corresponds to only 0.7% of Finnish energy consumption in the same year. This appears to be in stark contrast to the techno-economic potential of domestic biogas, which is estimated to be around 10 TWh annually [5]. A substantial bottleneck has been encountered in agriculture, where most of the biogas potential is found.

In Finland, current ambitions for biogas rely heavily on the use of biogas as vehicle fuel, as in other Nordic countries [6]. Recently, the Finnish biogas actors jointly declared that Finland should aim for 4 TWh annual biogas production by 2030, where half of the production would be generated from agricultural biomasses [7]. Due to the availability of manure and other farming activity side streams, regions with a high number of livestock farming systems especially are regarded as suitable for agricultural biogas production [8]. Although farmers are interested in biogas production, poor profitability, long transport distances, and high investment costs have hindered the development of rural biogas systems [9]. Moreover, the multidimensional nature of biogas in national policy planning often results in a patchwork of policies [10], which creates ambiguity in the biogas sector.

The dominant top-down policy planning often addresses the biogas sector through techno-economic lenses [11, 12]. Biogas solutions are evaluated primarily at the national level and in a quantitative manner, focusing on the cost-effectiveness of renewable energy and emission reductions generated [13]. This setting downplays the diversity of actors and their opinions at a subnational level and qualitative aspects affecting the biogas systems locally.

According to Huttunen et al. [14] a policy analysis of the biogas sector would benefit greatly from local and regional actors' perspectives, as these actors witness the acute effects of the national biogas framework. Moreover, understanding the drivers and constraints regional actors perceive in their area and evaluating them against the nationally set policies would help evaluate the functionality of the policy framework and the investment environment they generate in practice. In addition to the evaluation of existing policies, a bottom-up approach could uncover new insights from a regional perspective, which should be considered when shaping a more effective national biogas policy framework. This

paper aims to explore these local perceptions from the perspective of actors in the Finnish region of Northern Savonia. This region was chosen due to the large potential for agricultural biogas production and the presence of an emergent group of biogas actors in the region. For this paper, the research questions are as follows:

1. How do biogas actors in Northern Savonia perceive the Finnish biogas sector?
2. What are the drivers and constraints for biogas in Northern Savonia?

Disorganisation in the biogas sector

Qualitative social science research on biogas systems can be divided roughly into two groups: the national level and the regional and local level. National level analysis regards biogas as an emerging technology that can contribute to national energy production and emissions reduction efforts in the transport and agricultural sectors. National case studies aim to give a comprehensive overview of the biogas sector in a certain country and often utilise document analysis of official policy documents, research reports, and statistical data [11, 15–17]. Cross-country comparisons based on literature reviews and stakeholder interviews are also common, affording an insight into differences between policies, frameworks, and applications of biogas systems between countries [9, 18–20]. The national level approach emphasises the importance of policy frameworks, cooperation across administrative sectors, and the national characteristics of different countries. The materials and sources used thus reflect the national level perception of contemporary issues and developments. They therefore often present the biogas niche as a unanimous advocacy group, lacking the voice of the local actors engaged with the actual investments at the grassroots level.

Regional and local level analysis takes interest in the practical level, where concrete investments in biogas technology occur [21–23]. In contrast to the national level, decision-making power is held by farmers, municipal politicians, and companies, which hold varying ties to the actors who represent them in the national level analysis. Actors collaborate by forming networks, establishing shared goals, and working towards a functional biogas system [24]. However, local actors may have different understandings of both the problem settings and the solutions biogas systems can offer [25]. When the nationally set biogas policies and targets are coupled with local realities, the interests of all value chain actors need to be formulated into a clear goal [24].

Within the biogas niche, actors are generally less organised than in other renewable energy niches and

¹ Land fill collection sites (33 plants) and the corresponding energy production (190 GWh) were excluded from the total.

therefore have weaker lobbying power and public visibility in the national domain [26]. Actors from agriculture, energy production, and transport approach the biogas sector and policies from their respective positions in the biogas value chain with their perceptions and interests. Prominent points of divergence between actors' interests can be observed in the Finnish public debate on biogas, where multiple conflicting narratives on the role of biogas have been distinguished [12]. At local and regional levels, actor networks have been observed to grow even more heterogeneously due to the context sensitivity of local biogas planning [25]. However, the functionality of these actor networks is essential for successful biogas planning at the local level [24].

Drivers and constraints in the Finnish biogas sector

The existing literature on the Finnish biogas sector shows rather similar drivers and constraints compared to other European countries [9]. In particular, when moving from waste-water sludge and biowaste to agricultural residues, the production of biogas has suffered from low economic feasibility [11, 27]. Whilst renewable energy, emission reductions, and bioeconomy goals are generally favourable for biogas, the uncertainty of political decisions and incoherent subsidy schemes have hampered the sector [9, 11, 14].

As a geographically large and sparsely populated country, the transport distances of both feedstock and biogas pose an economic limitation to plant sites in Finland. In addition, gas distribution and fuelling infrastructure are also rather limited, and they concentrate on the southern part of the country, which limits the cost-effective distribution of biomethane [27]. The lack of a gas-operated vehicle fleet especially in heavier hauling vehicles, and the increasing number of electric cars have created uncertainty over the viability of biomethane in the transport sector, despite the policy goals framing biogas mainly as a transport fuel [9, 17, 28]. Finland's grass-based livestock system provides a large resource base for biogas production through manure, grass, straw, and other agricultural materials [5]. Although farms are generally interested in biogas production in terms of both energy production and nutrient cycling, the upfront costs of building a biogas plant and the small market volume of both biogas and recycled nutrients limit investments [9].

Generally, the Finnish biogas sector suffers from a chicken-or-the-egg dilemma [11]. In the lack of stable demand, potential producers are hesitant to invest in biogas production for fear of facing poor demand for biogas. Moreover, the perceived risks of being an early bird investor in a novel technology may cause concerns amongst potential investors also in Finland [29].

Table 1 Respondents' position and knowledge of the biogas value chain

	Agriculture	Production	Distribution	End-use	Administration
R1	P	x			
R2	P				
R3	P				
R4	x	P			
R5	x	P			
R6				P	
R7		x	P	x	
R8	x				P
R9		x		x	P
R10	x		x	x	P

The ten respondents held different positions (P) and had differing knowledge regarding local and national biogas value chains (x). The "administration" column was filled in only for the purpose of three respondents' positions

Similarly, end-users are hesitant to invest in gas-operated technology without a guaranteed supply of biogas. What is more, the lack of proven economically viable business models and functional value chains limits the diffusion of biogas systems, especially when it comes to connecting farms to energy production [9].

Methods

The present study's empirical material comprised interviews of ten individuals from the Northern Savonian biogas sector. Northern Savonia is the sixth-largest administrative region by population in Finland, consisting of 19 municipalities as of 2021. Recent findings show a large resource base for biogas production in the area [30], as 13% of beef cattle farms and 14% of dairy farms in Finland are located in the region. Considering only available manure feedstock from the region's 1133 agricultural enterprises, approximately 395 GWh biogas could be generated annually [30]. The techno-economic energy potential from all agricultural residues and side streams is estimated to be 587 GWh annually, which ranks the region as fourth out of the 13 counties in Finland [31]. In addition, actors in Northern Savonia have recently demonstrated interest in promoting biogas in the area [32, 33]. Yet, many actor groups have only recently begun to be formed, and investments have not been realised in the area, making Northern Savonia an ideal subject for observing diverse perceptions in the biogas niche in its early development phase.

The present study's ten respondents were chosen to represent farmers pondering biogas investment, dairy and gas distribution companies operating in the region, as well as potential end-users (Table 1). In addition, public officials from both municipal and regional administrations were included. It should be noted that

the terms *local* and *regional* are used throughout this study. Although the interviews were collected in the geographical region of Northern Savonia, the perceptions participants held tend to have both local and regional characteristics, depending on the question. Therefore, we opted to use both terms to give an accurate description of the answers collected. Generally, local aspects are prominent at a farm level, whereas industry actors tend to adopt a more comprehensive regional perspective. The interviews were conducted and recorded remotely via Microsoft Teams in January 2022.

The interviews were held as semi-structured active interviews over eight sessions, focusing on recent developments and the possible prospects of biogas in the region. Compared to more traditional passive interviews, the method of active interviewing [34] was preferred due to its ability to engage with the themes uncovered during the interview process. The major difference between active and passive interviews lies in how the relevant information is created and collected. In more traditional interview methods, a respondent is considered a holder of information. Therefore, the researcher's role is to find the right questions to extract the information relevant to the study from this holder [35]. In contrast, active interviewing invites both the interviewer and the respondent to contribute to the creation of new information. Both participants are encouraged to discuss the topics at hand and to reflect on their views and opinions collaboratively, allowing information to be exchanged, and new ideas to emerge. Due to the participatory nature of active interviews, the researcher will have a greater influence on the content of the interviews and thus on the results generated from them. In turn, the successful employment of active interview tactics can enable more fruitful dialogues on the research topics than in traditional interview methods [36]. In this study, active interview tactics were found helpful as the focus and expertise of the respondents varied. For example, when discussing quite polarising topics such as agriculture's effect on the climate, it was found fruitful to empathise with farmers' views on the matter to generate a more inviting discussion. Similarly, a more technical expert-to-expert discussion approach was adopted when interviewing actors with a more comprehensive knowledge of the Finnish biogas sector.

Thematically, the interviews comprised two parts: in the first, questions and discussion revolved around the role of biogas in national politics. The interviewees especially discussed the recent developments in the Finnish biogas sector and the national policy environment. The second part of the interview was more closely related to the Northern Savonian biogas sector. There, the discussion was more concerned with expectations and opportunities

in the biogas sector, as well as the constraints and threats the interviewees identified. The interviews lasted 1–1.5 h and followed an interview guide tailored individually for each respondent. A predetermined pool of 30 questions was established (Appendix), from which around 15 questions were selected for each respondent, based on their affiliation and expertise. Before the interview, a set of two or three questions was sent to the respondents. Although the interview guides were utilised as the basis of the interviews, topics emerging outside the guide were neither uncommon nor undesirable, as they provided a unique insight into the themes the respondents perceived as important.

The interviews were transcribed and analysed via qualitative content analysis [37]. The content of the interviews was segmented into excerpts, reduced into codes, and sorted into an analysis matrix. The matrix consisted of thematic categories inspired by the PESTE framework, similar to that used by Winqvist et al. [9], with an additional category for value chains, and the position of the discussed issue in the biogas value chain (*supply* or *demand*). In the context of this study, the thematic categories were understood as follows: (1) *political factors*: influence of political and administrative actors and policy instruments; (2) *environmental factors*: influence of ecological concerns such as climate, soil quality, and air quality; (3) *social factors*: influence of socio-cognitive factors, values, and mental paradigms; (4) *technical factors*: opportunities and limitations related to technical functionality, availability and reliability of biogas plants, distribution, and end-use technologies; (5) *economic factors*: issues pertaining to the profitability of different actions in biogas operations, as well as actors' capability of investing in biogas production or end-use technology; and (6) *value chain*: perceptions of how to organise the biogas value chain functionally. Thematic categories four (technical factors) and five (economic factors) were coded separately but combined during the analysis due to overlapping codes.

Some respondents held positions allowing them to answer from both supply and demand perspectives, and their answers could be categorised in both demand and supply categories accordingly. Throughout the analysis, the respondents' roles in the biogas sector were also tracked within the codes. The content within each cell of the analysis matrix was condensed into broader subcategories. To distinguish consensus and dissensus topics between the different sides of the value chain, the subcategories were further compared between the corresponding production and demand categories. The analysis was conducted within Nvivo 12 for Windows software.

To mitigate any distortions arising from the researcher's active participation in the interviews, the results and conclusions generated in the analysis were presented to a group of researchers with both practical and academic knowledge of biogas-related issues. The session was held in late February 2022. The members of the group were encouraged to spot and comment on any surprising or contradictory findings in the analysis, forcing the researcher to explain and evaluate the validity of the results in question. Some questions were raised by the group members, resulting in the data of those few findings being re-evaluated, and the resulting findings were revised. In this paper, the results are presented with contextual references of the recent developments and research in the Finnish biogas field. The purpose of this choice is to reflect the context that the interviewer raised during the interviews.

Results

Political factors

In Finland, three investment grant schemes are currently in place for biogas production: (1) energy aid for commercial energy production; (2) a rural investment grant for farm-scale production, where biogas is used on the farm; and (3) a rural corporate grant for farm-scale production if the farm wishes to sell the biogas [38, 39]. The overlapping system of the three schemes was deemed to be confusing by the respondents, as they are operated by different agencies, employ different subsidy levels, and set different limitations to the use of the energy produced. In addition, the respondents reported that constant shifting in the subsidy levels and entry requirements made a comparison of the subsidy systems quite difficult.

For 2021–2022, the rural corporate grant was temporarily raised to a level of 50%, which was considered a preferable level by actors for both production and demand. However, the temporary increase was stated to occur at an unfortunate time, as high energy and fertiliser prices hampered the profitability of primary production, reducing willingness for new investments. Many respondents believed that if the timing had been better, several additional investments would have been launched. The respondents also regarded the 2-year timeframe as rather limited for planning and constructing a biogas facility. It was hoped that the upcoming feed-in tariff for manure and nutrient cycling would generate more predictability for biogas production, especially by the production actors, although some respondents preferred the introduction of more demand-focussed solutions. However, as Finland had recently become a member of the common European gas market, concerns were raised about whether the introduction of demand-side policy

instruments could lead to increased biogas imports and the hampering of domestic production [40].

In 2022, biomethane was included in the distribution obligation of biofuels [41]. The previous tax exemption for biomethane was simultaneously removed, as the support schemes were considered overlapping and thus forbidden under the EU's guidelines for national subsidies [42:75]. Although some respondents raised concerns about whether the demand effect would offset the increased consumer price for biogas, the increased price of natural gas during 2021 made biogas a rather competitive option. Moreover, the respondents regarded the distribution obligation as a market-based solution that would increase the demand for biogas and correspondingly encourage more actors to become involved in biogas production. However, the removal of the tax exemption left some respondents confused about whether the taxation would differ for biomethane in heat and power production from that for transport use.

Concerning the overall biogas policy framework, the respondents' consensus was that the publicly announced policy targets were too ambiguous, and the subsidy system was constantly being altered. Moreover, the subsidy system was regarded as lacking long-term predictability. Although the actual subsidy levels might be generous in a short time frame, they were often discontinuous, without a recognition of the implications of the upcoming changes. One respondent reported that they had already planned a biogas investment twice, with the window of opportunity closing before the investment on both occasions: first, from electricity production; then, from passenger vehicle fuels. Rapid temporal shifts in publicly stated policy goals failed to provide clear signals to the respondents, which, with unpredictable and discontinuous support schemes, reduced their willingness to commit themselves to a biogas investment. Ambiguous discussion of upcoming tweaks to the subsidy system was even considered harmful to the biogas sector, as potential producers became afraid of losing benefits from the promised future subsidies and refrained themselves from investing until the hinted subsidies were implemented.

New subsidy systems come and go. They might be rather short-lived: eighteen months; two years; three years. If we consider [biogas] investments, the time needed for planning, construction, and the operating times, it's too short. [...] Some actors aren't confident the subsidies will continue. (R10). We should create the necessity [for biogas] through the market. I feel that the distribution obligation is a more market-oriented policy measure than the investment grants, and that's the way forward. (R7).

Long-term investment plan subsidies are needed to support it. Not just for a single governmental term, but for at least until 2030. (R4).

Environmental factors

Finland has an ambitious target to become climate neutral by 2035 [43], which will require vigorous large-scale emissions reductions in all sectors. Due to its rather low contribution to national emissions reduction efforts, the agricultural sector has faced harsh criticism [44]. Emissions from the Finnish agricultural sector have remained around 14 Mt CO₂-eq. annually, without any major changes during the last decade [45]. In this study, the respondents agreed that the general energy and climate policy framework has been beneficial for biogas, as biogas gains recognition and legitimacy when included in national, regional, and local climate strategies. Biogas was considered an especially beneficial solution in areas with many farms due to its synergies with rural development, water effect mitigation, and nutrient recycling improving synergies beyond emissions reduction and renewable energy production.

According to the respondents, consumers had become more aware of their lifestyle emissions. Increasing awareness has thus forced companies to reconsider their energy and material acquisition, logistics, and public image. Companies were considered to be more interested in their products' lifecycle emissions, aiming to reduce and offset the emissions produced. The respondents argued that biogas could especially reduce emissions in logistics, thus improving companies' public image and providing consumers with more climate-friendly products. Moreover, the respondents mentioned that especially in the road-hauling sector, there has been growing interest in biomethane-operated vehicles, which they saw as giving a competitive advantage to their services. However, many respondents also noted that neither consumers nor companies were at the time of the study willing to pay a sufficient climate-premium for low-carbon services or products. It was indicated that climate awareness had yet to transform into a direct market signal, which would steer companies to choose low-carbon alternatives over fossil fuels.

In agriculture, the respondents noted multiple environmental drivers for biogas production. Processing manure in a biogas plant reduces the need for clearing more land for manure spreading and allows easier expansion of the farm. On-farm renewable energy production and nutrient cycling were considered significant drivers, especially with rising fertilisers and energy prices. Similarly, solid residues from an anaerobic digestion process could be refined into bedding for

cattle and other domesticated animals, thus reducing dependency on peat. Regarding the key drivers for biogas production on farms, the respondents considered these to be self-sufficiency and environmental benefits. Whilst the feasibility of production was mentioned as essential, the actors considered it more as a boundary condition than the primary purpose. The respondents anticipated that the climate effect of agriculture would motivate many farmers to invest in biogas production. Indeed, they argued that farms that wished to continue as food producers in the future would have to justify their existence by reducing the emissions of their farming activities. Although the recent climate discourse was found to be putting healthy pressure on farmers to seek solutions, it could also feel exhausting, creating a passive and bitter atmosphere.

The motivation comes from the customers. Those who want to switch to biogas based on general interest or an individual desire to reduce emissions are in the minority. (R6).

At times, the climate discourse feels somewhat distressing. But it also makes you think about how we could contribute more. (R2).

Social factors

In the present study, the respondents stated that mental images and previous experiences with biogas technology and business activities greatly affected their willingness to commit themselves to biogas production and gaseous end-use technologies. Successful examples also created a forward-looking optimism for the future of biogas technology, which was deemed vital for biogas systems to emerge. A forward-looking attitude was perceived as important especially in the transport sector, where actors were pondering the long-term availability of fuel before investing in gas-operated vehicles.

The respondents emphasised that pilot projects in varying unit sizes and areas with different geographical conditions built confidence in the feasibility of biogas plants in different agricultural settings, thus bolstering investment decisions. Pilot projects and practical examples were important in both production and consumption, as the front-runners took the increased risk of investing in a niche technology with limited business models and markets. At the consumption end, biogas was perceived to enjoy the status of an environmentally friendly technology, and its use was supported by local citizens and companies seeking options to reduce their emissions. Equally, bad experiences and negative rumours were stated to be harmful to the diffusion of technology, especially amongst agricultural and road-hauling actors,

as information spread quickly within these professional communities.

Respondents wondered if farmers shied from the role of an energy producer if the activities were considered too disconnected from the role of a food producer. Moreover, the respondents stated that investment in biogas production came with the risk of unsuccessful investments and an increased workload in operating the biogas plant. The importance of keeping the workload reasonable was also emphasised, and respondents from the farming sector noted that this increase was not usually accounted for as a financial cost when the profitability of a biogas plant is evaluated by outsiders. However, it was also stated that careful planning of the investment and the farmer's personal interest in biogas technology would help overcome these constraints. As the responses below show, successful profitable examples were mentioned as a means of nudging farmers to accept a secondary role more easily as an energy producer.

Farmers seem to find the role of an energy producer a bit distant. But I'm positive they will be more interested when they see that the business model can be functional. (R4).

It's certain that no farmer will be willing to deliver manure or farm energy crops unless it comes with added value. And then there's the public image, which cannot be currently downplayed on any occasion – even on farms. (R1).

Technical and economic factors

In recent years, biogas has been proposed as a solution for the transport sector. In 2017, the Finnish government set a target of 50,000 gas-operated passenger vehicles and promised the construction of sufficient infrastructure to support it. [28:33] According to the respondents, the official target had revitalised the biogas sector and shaped the business atmosphere and efforts in the sector into a more professional form. However, they felt that these efforts were hampered when major car manufacturers decided to focus their R&D efforts on electric vehicles. Many respondents deemed this development a missed opportunity and felt that gas-operated vehicles were denied the ability to develop through market-based means. Instead, biogas was effectively side-lined because of political decisions, and by doing so, a major driver for the biogas sector was rendered ineffective. Nevertheless, some respondents noted that biogas would still be an ideal fuel for passenger vehicles in rural areas, envisioning a transport system using multiple alternative low-carbon fuels.

Although the future of low-carbon passenger vehicles was perceived to mostly consist of electric vehicles,

heavier gas-operated vehicles in road hauling were reported to be receiving growing interest in the biogas sector. In their response, the respondent from the hauling sector noted that the vehicle technology was considered reliable, and lorry manufacturers were continuing to provide gas-operated lorry models, implying that the manufacturers were confident about biomethane in the transport sector. It was also said that biogas gained additional drivers from increasing gas prices, which could offset the more expensive initial investment and maintenance costs compared to a diesel-operated vehicle. However, gas-operated vehicles were reported to be currently unable to substitute diesel engines in the heaviest vehicle group with the most mileage due to technical limitations. One respondent feared that the replacement rate of gas-operated lorries would remain rather low, which increased the investment risk of limited fuel availability in the future.

The distribution infrastructure was depicted as a key piece of a successful biogas system. At the time of the study, the gas distribution grid and fuelling infrastructure in Finland was considered to be rather limited, with it mainly being concentrated in Southern Finland. Limited infrastructure was the single most significant element for the respondents, and its development either made or broke the biogas system. For hauling companies, limited infrastructure was deemed to cause problems and risks in their logistics. Having a limited and sparsely spaced fuelling station network would mean that in the case of an empty or malfunctioning pump, other fuelling stations might not be available in the area. Moreover, the spatial distribution of fuelling stations was considered important. If the pumps were in remote areas outside the main road network, for example, the attractiveness of acquiring a gas-operated vehicle was deemed to be low.

Geographically, biogas production was deemed suitable in rural areas, with easy access to potential feedstocks. Therefore, some respondents stated that biogas should be produced on farms, where feedstock and energy were produced and consumed onsite. However, the respondents agreed that these rural locations were rarely close to potential consumers and that larger, more centralised biogas facilities were more economically viable. The respondents stated that long transport distances greatly hampered the feasibility of biogas production, making the siting of larger scale production plants difficult within the range of an adequate amount of feedstock. Though larger farm-scale plants, sometimes owned by farmer communities, have been considered, the ongoing profitability crisis in agriculture was deemed to make it difficult to secure funding for the investment. Some respondents wondered whether the high price of mineral fertilisers could also imply that manure feedstock

would become more valuable in farming activities. This was seen as likely to reduce their willingness to sell the feedstock to biogas production in a larger centralised unit.

The risks will be carried by the first actor who sets up the fuelling pump. How long it will take until people and enterprises can invest in gas-operated vehicles? (R10).

From a technical perspective, the vehicles have been very reliable. [...] Yet there have been issues with refuelling, when the pumps have failed or they've run out of biogas. (R6)

I don't really believe in biogas in passenger vehicles. While we still have some gas-operated cars in Finland, electric vehicles will become much more popular, even in Northern Finland. (R9)

Value chains

Biogas systems tend to grow unevenly for the production and demand of biogas, which calls for collaboration in mediating and matching actors across the local value chain. Fallde and Eklund [46] suggest that this task falls to a system builder—an actor with a vision and ability to coordinate the construction of a biogas system. The influence of such actors has been recognised by Suonio [47] when investigating other emergent local biogas systems in Finland.

Connecting production with consumption was regarded as a key element for successful biogas systems by the respondents. Without sufficient production, consumers were perceived as hesitant to invest in gas-operated end-use technology. Simultaneously, in the absence of demand, the production of biogas appears risky and unattractive. According to the interviews, local municipalities could act as the coordinating motors for biogas systems. The respondents agreed that municipal actors could promote the use of biogas by including the technology in their development strategies and bringing potential actors together to envision a desirable biogas system. Furthermore, the respondents stated that municipalities could influence and enable both the production and consumption of biogas through tangible investments. In production, municipalities could construct centralised biomethane plants, giving the farmers an option to sell their biogas for further upgrading without the need to upgrade it on the farm. Consequently, municipalities could generate a stable demand for biogas in residential heating and power generation through public investments in gas technology. Alternatively, municipalities could invest in fuelling stations or alter their tendering rules for public transport acquisitions to be more favourable for biogas.

Thus, the municipality would bear some of the risks related to early-bird investments, allowing commercial actors an easier entry into the sector.

At the time of the study, the respondents found municipalities too passive in their efforts to promote and build biogas systems. Although biogas had gained exposure in recent years via regional biogas reviews [32, 33], some respondents felt that too little effort had been made to launch the actual investments. Whilst reviewing the local conditions for biogas systems was deemed important, continuous reports on the biogas topic were regarded as “yet another biogas report”.

Although the role of a system builder was deemed important, especially in the emergent state of a local biogas system, the growth of the actor-network was considered vital for the long-term stability of biogas. Although the majority of the respondents stated that the initial market could evolve locally, it would have to be large enough to attract new actors nationally. The dairy and food industry, marine logistics, and flexible energy production and storage were mentioned as potential customers for biogas at a national scale. An expanded biogas market could also act as a stimulus for more unconventional biogas cooperation between industry and agriculture by solidifying biogas as part of the national energy mix.

When asked about a preferable biogas value chain in the Northern Savonian region, the responses were somewhat contradictory. Farmers who valued farm-level self-sufficiency and closed material loops especially hoped that biogas production could emerge as farm-based. While not out of the question, farmers expressed their reluctance about selling feedstock products to large commercial biogas plants. Concerns were raised about the small income generated from feedstock sales, and whether the emissions reductions would not benefit the agricultural sector if the biogas was sold as transport fuel. In contrast, some respondents regarded a solely farm-based system as inadequate for generating sufficient production to expand the market. Production in a collective of farms or selling farm-produced biogas to a larger unit for upgrading was seen as a mid-route solution.

There is a gap between the end-user and the producer. On the production side, it's easy to think that if there is production, there will also be demand. But it's not that simple, and that's probably one constraint in the biogas planning. (R5)

From our perspective, the best model would be that farms could use the gas as electricity on the farm. And when there's surplus gas, it could be sold. (R1)

Table 2 Drivers and constraints in agricultural biogas production

	Drivers	Constraints
Political factors	• Temporary rise in investment subsidies • Energy and climate policy support RE production	• Complicated subsidy system • Discontinuous policy instruments • Ambiguous policy targets
Environmental factors	• Nutrient recycling and RE production regarded as important • Emissions reductions on farms	• Emissions reductions will not benefit the agricultural sector • Climate discourse may feel exhausting
Social factors	• Farmers find biogas technology interesting • Positive experiences of farm-scale plants • Improved future operation conditions on the farm	• The added workload of operating a biogas plant • The role of an energy system actor feels too distant
Technical and economic factors	• Increased prices for energy and fertilisers • Additional income from feedstock or gas sales	• Poor profitability of food production • Challenges to securing funding for the investment • Production not located near potential consumption areas
Value chains	• Farmers are interested in collective biogas plants	• Limited examples of larger biogas value chains

Table 3 Drivers and constraints in biogas distribution and end-use

	Drivers	Constraints
Political factors	• Distribution obligation passively creates demand • Support for low-carbon investments and gas distribution infrastructure	• Differing taxation between end-use cases • Discontinuous policy instruments • Lack of demand-based policy instruments
Environmental factors	• Synergies with environmental goals and rural development • Local and regional climate initiatives • Consumers more climate-aware	• Consumers' awareness has not translated into a willingness to pay a climate premium
Social factors	• Biogas has a positive public image • Change of information between biogas actors	• Lack of demand-focussed initiatives • Risk of not-in-my-back-yard effect when investing
Technical and economic factors	• Gas-operated vehicles are considered reliable • Switch-fuel tactics available to substitute for natural gas • Possible markets in marine transport and flexible power production	• Limited fuelling infrastructure • Risk of empty pumps and pump malfunctions • Diminishing supply of gas-operated passenger vehicles • Risks of being an early bird investor • Small initial market
Value chains	• Municipalities dominated by agriculture interested in investing in biogas	• Farmers perceived as hesitant to sell gas or feedstock to a larger company • Lack of entrepreneurial attitude on farms

I think a purely distributed production model is too uncertain. I reckon that if we had a big actor distributing liquefied biomethane for ships, for example, that would create stability and motivation [for biogas]. (R5)

Summary of the results

The results suggest that drivers and constraints are perceived and valued differently, depending on which side of the regional value chain is observed. In production (Table 2), the drivers that are perceived as important focus on combining farming activities with profitable biogas production. Energy production, nutrient cycling, and replacing peat bedding result in monetary savings, additional income, and improved self-sufficiency. These also come with environmental benefits. Farmers are also interested in biogas technology, which may help mitigate

the increased workload and enable the current climate discourse to act more as a driving force. The poor profitability of food production places a major barrier to farm-level investment. Indeed, farmers' attention focuses on more acute matters, and securing finance has proved difficult.

In distribution and end-use (Table 3), the most prominent drivers arise from an increased awareness of companies, customers, and citizens. As consumers are increasingly interested in low-carbon products and services, biogas becomes a more attractive choice in the transport and energy sectors. Synergies with rural development and other environmental goals have been recognised in municipalities dominated by agriculture, where biogas has been included in local climate initiatives. However, consumer awareness is yet to translate into a willingness to pay more for climate-friendly services, negating the added revenue

from the biogas chain. In addition, the market size for biogas, especially biomethane, is currently limited in this study area due to the lack of a sufficient number of gas-operated vehicles, the novelty of gas-operated lorries, and the absence of a natural gas grid. Moreover, some respondents described the entrepreneurial attitudes of farmers in Northern Savonia as somewhat conservative, which was manifested in poorly planned biogas investments and general inflexibility in creating a sufficient production infrastructure.

Both sides of the value chain share the climate and energy policy driver, which supports renewable energy and emissions reduction efforts. Recent developments in the policy instruments were also regarded as beneficial: an increased investment subsidy in production and distribution obligation, especially in distribution and end-use. However, both sides noted problems with the current policy framework and legislation due to their perception as somewhat confusing and discontinuous.

Discussion

In their study, O'Connor et al. [29] reviewed factors limiting the implementation of small-scale rural biogas plants in Europe. Our results align with their findings when it comes to ambiguous policy frameworks, limited access to funding, and a lack of trust in the economic viability of biogas production. However, the biogas and renewable energy sectors were perceived to have a positive image in Northern Savonia, and here our results contrast with the general European trend. Biogas remains one of the few means to reduce emissions in agriculture, which enjoys support from farmers and is promoted by both agricultural and environmental interest groups in Finland [48, 49]. Moreover, the not-in-my-backyard mentality in biogas siting has not been largely reported in Finland, yet the biogas actors are aware of the risk both in Northern Savonia and Finland as a whole [9]. Diversified actor networks between private and public actors with shared goals are crucial when building functional business models at the local level [25]. In the case of Northern Savonia, public actors at the local level were deemed central actors in the biogas network, a proposition supported by the literature [24, 50].

Similarly, our results support the previous studies on drivers and constraints of the biogas sector in Finland [9, 11, 27]. The economic feasibility of biogas production was considered to form the basis for a successful biogas system. As the current ambition is to use biomethane in the transport sector in Finland, expanding the distribution and fuelling infrastructure was deemed vital in connecting production with consumption in Northern Savonia. These similarities between existing literature and the results can be a result of the style

of active interviewing, where the interviewer's input relied on the existing literature of the biogas sector in Finland. Nevertheless, the regional analysis uncovered nuances between different interpretations of these issues. For example, production-side actors emphasised the complexity of the renewable investment grant system, whereas demand-side actors found the subsidy system too production-focussed, and were more concerned about the lack of demand-focussed measures and ambiguity in the taxation of biomethane in the policy framework. Moreover, concerns over the increased workload on farms or practical issues related to pump malfunctions may seem like small details in the national level policy setting, but they have a great influence on the individual actors pondering an investment.

Social, political, and environmental factors may play a significant role at the local decision-making level. Although the economic feasibility of biogas production will remain an important boundary condition for biogas systems, the results suggest that economic incentives can only go so far in stimulating the growth of the biogas sector if non-economic issues faced by local and regional actors are not addressed. This especially concerns farms, where decision making may fall to a single individual. In particular, on farms, mental images, rumours, and tone in the public discussion may have a strong impact on the decision to participate in emission reduction efforts [51]. Farmers may also find shaping food production to be more environmentally and climate-friendly valuable in itself, in contrast with the economically rational behaviour expected in national policy planning [52]. Furthermore, policy frameworks, which may appear logical, cost-effective, and technology-neutral in national decision-making, appear confusing and biased towards certain low-carbon solutions at the local level, similar to shallow policy narratives regarding the larger bioeconomy in Finland [53]. Ambiguous policy statements and promises can be harmful both in the short term, as investments in biogas may be postponed, and in the long term, as potential investors will lose confidence in the future of biogas.

The results of the present study suggest that the perceptions in the biogas niche do not appear homogeneous. Although actors in the biogas sector share the common goal of promoting biogas in the region, there appear to be two distinguishable and partly incompatible narratives concerning how to optimally organise the biogas value chain. On the one hand, actors close to agriculture wish to build biogas production around farms and food production, where emissions reductions would benefit farms and reduce the lifecycle emissions of agricultural products. This would imply a highly decentralised system of multiple

small-scale digesters, where biogas would be used to generate heat and power for on-farm use. Yet, on the other hand, some actors prefer larger-scale biomethane production, which could be applied in the transport sector for emissions reduction purposes and the expansion of biogas markets. However, biomethane production would probably require larger centralised production plants and a sufficient amount of feedstock within an economically viable radius. As a result, the decision-making power would inevitably shift from the farm level to the operators of production and distribution. In other words, targeting biomethane in the road hauling sector may seem attractive from national and commercial perspectives but may encounter local resistance from farmers if these concerns are not addressed [51].

Gustafsson and Anderberg [50] propose regional biogas systems as a middle ground between large, centralised biogas plants and on-farm digesters in the Swedish context. Connecting biogas production with demand could be easier on local and regional levels in the absence of nationwide national gas grid, which could encourage stronger collaboration between regional companies, municipalities, and farmers. However, there is an evident need for further research on feasible business models at a regional level that will satisfy all the actors involved and practical examples to prove their viability [29]. Furthermore, an adaptation of a more comprehensive perspective on biogas as a sustainability product [11] rather than addressing it as a mere renewable energy production technology would help better account for the benefits of biogas systems. Adding to this, Lindfors et al. [6] suggest that policy support for biogas systems should be divided more clearly between production and consumption, as some of these benefits are more clearly tied to either the consumption or production of biogas, and the support mechanisms should be targeted accordingly. This is not to suggest that supply and demand should be treated as separate entities. On the contrary, local cooperation between actors across the biogas value chains should already be established in the early-planning phase of the biogas system to ensure a common vision for the local biogas system and to enhance actor collaboration [24]. As the drivers and constraints between consumption and production are perceived differently, joint planning helps understand and mediate these issues across the value chain. Moreover, it also enables the building of trust between actors, which may contribute to common value creation and flexibility in the subsequent steps of the planning processes, increasing their probability of success [54]. Although there will probably be no one-size-fits-all solution for the Finnish biogas sector, acknowledging and accepting that

a large variety of solutions can coexist could instead be a way to stimulate the biogas sector in Finland.

Conclusions

This study focussed on local perceptions of the Finnish biogas framework and investment environment in the region of Northern Savonia. Local actors perceived the poor economic feasibility of biogas production, limited fuelling infrastructure and the lack of proven business models to be the main constraints in the region. Furthermore, historically ambiguous policy targets and discontinuous subsidy systems caused concerns along the biogas value chain. However, the recent changes in the subsidy system, synergies with rural development and local low carbon initiatives in the region were considered a driving force for the local biogas system. In addition, the importance of social factors was highlighted. Mental images, rumours and tones in the public discussion were deemed important not only by the farmers, but also by other actors.

Whilst the biogas niche may appear unanimous in the national context, there can be internally diverse opinions in different parts of the biogas value chain at the regional level. Differences were noted especially in the preferred arrangement of the biogas value chain. At the local level, production and demand perceive different drivers and constraints, sometimes with conflicting perceptions of how to solve them. Techno-economic framing of the biogas sector presents an incomplete picture of the nuanced perceptions of local actors. Moreover, social, political, and environmental drivers may affect farmers' and other actors' willingness to invest in biogas technology. For future studies, careful research will be required to uncover profitable business models for different regions and actor groups operating in the biogas sector.

Appendix: Interview questions pool. English translation of the original questions (in Finnish).

Opening questions

1. Could you briefly describe your expertise in the biogas sector?
2. Based on your experience, can you briefly summarise the recent trends affecting the development of the biogas sector in Finland?

National policy framework

1. How would you describe the general picture of Finnish biogas policy as it is right now?
2. What kind of challenges are there in the biogas sector?
3. What kind of strengths are there in the biogas sector?
4. Do you think the role of biogas could/should increase in Finland in the future?
5. What kind of opportunities do you anticipate?
6. What kind of threats do you anticipate?
7. How do you perceive the recent media discussions regarding biogas?
8. What is your perception or experience regarding the role of farms in developing the Finnish biogas sector?
9. What should be done to make farms more interested in biogas production?
10. How predictable is the investment environment?

Regional development in Northern Savonia

1. Do you find the national policy targets and measures for biogas, especially regarding heavy-duty transport, functional in this region?
2. Do you find the current policy measures such as subsidies and legislation to be functional and beneficial in this region?
3. How would you describe the ongoing biogas projects in the region?
4. What is the general atmosphere regarding biogas in the region?
5. In an ideal situation, how would you organise the biogas value chain in this region?
6. What measures would be needed for this ideal situation to be realised?
7. What kind of benefits do you see in biogas production for this region?
8. How important is nutrient recycling from biogas production in this region?

Biogas actors in Northern Savonia

1. Do you feel farmers in this region are willing to engage in biogas production?
2. Why do you think (what kind of motives are there for farmers) farmers engage in biogas production?
3. Why do you think (what kind of motives are there for) end-users wish to use biogas?

4. Do you feel that actors in general are well-informed and knowledgeable about biogas production and use?
5. Which actors should be the front-runner or system-builder in this region?
6. What kind of support would the front-runner require for the biogas system to be successful?
7. How could actors in your company/sector participate in building biogas systems in the region?
8. What kind of biogas initiatives would be preferable for your company/sector?

Closing

1. Could you reiterate the three most prominent drivers for biogas production (the level of analysis deliberately left ambiguous)?
2. Could you reiterate the three most significant constraints for biogas production (the level of analysis deliberately left ambiguous)?

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Author contributions

Conceptualization: A.K., R.S.; methodology: A.K.; investigation: A.K.; writing—original draft: A.K.; writing—review & editing: all authors; Supervision: K.M., R.P., R.S.; project administration: R.S.; funding acquisition: R.P., R.S. All authors read and approved the final manuscript.

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Data availability

Interview data is not available to protect the privacy of the respondents.

Declarations

Ethics approval and consent to participate

This study complies with the Finnish National Board on Research TENK guidelines on the ethical principles of research with human participants and ethical review in the human sciences in Finland, applied from 10 October 2019 [55]. Under the guidelines, no ethical review statement was required for this study. Informed consent was obtained from all subjects involved in the present study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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