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State’s perception of biogas in Finland

Content analysis of key policy documents 2001-2016

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Abstract

Biogas has emerged as a potential technology to provide greenhouse gas reductions in energy sector. Finland has historically been reliant on bioenergy in energy production, and bioenergy is perceived as one of the primary tools in decarbonizing Finnish society. Despite the heavy emphasis on bioenergy, development of the biogas field has been rather slow in Finland. This study describes the developing perception of the Finnish biogas field through seven key policy documents between 2001 and 2016. A state-centric perspective is adopted to give insight on the developments in the biogas field. State's behavior is suggested to be a result of interpretation and perception between developments in global and domestic policy domains. States seek to shape the national energy system to correspond the perceived pressure from landscape developments. In the rise of climate agenda, pressure from landscape has grown significantly, yet the state seems to perceive domestic biogas production as an inefficient and expensive solution, compared to other alternatives. Energy and climate centric perception in decision making seems to overlook many of the distributed synergies of biogas production, making a proper value judgement too complex. Clarifying and further strengthening the connection between circular economy, enhanced local economy, security of supply and additional environmental benefits might result in a more cost-effective perception of the biogas niche. As important is to give recognition to practical aspects of biogas development, as centralized policy making might not give enough attention to the practical realities, which actors face on the local level.

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1. INTRODUCTION

Recently, there has been a rapidly growing interest towards renewable energy production. Biogas has emerged as one of the potential solutions, due to its high, yet underutilized potential in multiple countries. Especially in Europe, there has been a growing interest to integrate gaseous bioenergy more closely to national energy mixes (Scarlat, Dallemand, & Fahl, 2018). Finland has been historically dependant on wooden industries and has a long history on bioenergy solutions. Biogas has been recognized to synergize well with the national conditions of a sparely populated northern country with large amount of underutilized resources for biogas production. Despite the fact that increased use of biogas has been on the political agenda for decades, no significant development has occurred. Simultaneously in certain countries, such as Germany and neighbouring Sweden, biogas has established its place in the national energy mix (Capodaglio, Callegari, & Lopez, 2016).

Certain research efforts have been made to analyse the poor condition of the Finnish biogas field. Researchers have explained the phenomena by referring to poor economic conditions of biogas production (Uusitalo et al., 2015), lack of cohesion between policy instruments and policy goals (S. Huttunen, Kivimaa, & Virkamäki, 2014) and poor overall understanding of the biogas field (Winquist, Rikkonen, Pyysiäinen, & Varho, 2019) as possible explanations. However, no attempt is made to explain this development from the perspective of state behaviour. Central decision makers possess strong influence to support emerging niche technologies (Avelino, Grin, Pel, & Jhagroe, 2016), such as biogas, if perceived fitting from their perspective. In general, policy frameworks have recognized the biogas agenda, but the perception and framing of this niche technology matters greatly to how a state approaches it.

This study focuses on the perception on biogas niche in Finland. Development of this perception is traced through key energy and climate related policy documents between 2001 and 2016. Utilizing qualitative content analysis, documents are analysed in a systematic fashion to describe and analyse the the development, trying to understand a state-centric behavior pattern on the matter. Therefore, research question for this study is:

How have the Finnish official policy documents perceived biogas during 2001-2016?

Additionally, this study seeks to give insight on states behavior in energy transition, and discuss developments found in the analysis against the theoretical framework as well as recent literature from biogas research.

This study is organized as follows: **Section 2** acts as a background chapter, and gives an overall picture of the biogas in relation to climate change mitigation. Biogas processes and possible utilization pathways are described, followed by the role and potential of biogas in Finland. This section concludes with a review on existing scientific literature about the Finnish biogas field, supplemented with selected insights drawn from other European countries. **Section 3** describes the theoretical framework used to discuss findings of the analysis. Theoretical foundations from multi-level perspective and neoclassical realism are explained, after which theory synthesis is made to explain state behavior in relation to three analytical levels of multi-level perspective. Section concludes with a discussion on possible limitations the theory synthesis might connote. **Section 4** covers the methodology and materials used in this study. Overview on qualitative content analysis (QCA) is given, followed by assessment of validity and reliability of the methodology. Portrayal of the practical application of the QCA in the analysis is provided after. Lastly, policy documents chosen for the analysis are described. **Section 5** engages with the practical content analysis and describes the process in step-by-step fashion. Reasoning for the choices and observations, made during the analysis, are documented throughout the section. **Section 6** gives a portrayal of the key findings, by describing the head categories found in the content analysis. Systemic review on their contents is provided with examples. Additionally, measure of frequency and possible changes observed within the head categories are documented here. **Section 7** discusses the results of the analysis. Findings in the policy documents are discussed firstly against the theoretical framework to highlight role of state in the MLP, followed by discussion on more practical policy matters, found during the analysis. **Section 8** gives concluding remarks of the thesis.

2. BACKGROUND

2.1. Prospects of biogas

Biogas is a gaseous form of bioenergy, which is mainly produced from organic matter via anaerobic digestion process. In the process, sludge of organic matter is held in an airtight container at a temperature around 50 degree Celsius, where the matter decomposes into a mix of carbon dioxide and methane (Coley, 2008). A large variety of feedstock may be utilized for the process, including biowaste from industrial or municipal origin and sewage sludge. Agricultural feedstock may also be utilized, including residues such as cattle manure and grass silage, but also dedicated energy crops, cultivated and harvested for the purposes of biogas production. Anaerobic digestion utilizes decomposition as the main process for gas production, and therefore requires maintaining of suitable conditions in the process. This also poses some limitations to the feedstock utilized, especially in the terms of active bacteria and sufficient water content. Methane composes around 50-70% of the produced gas mix, and is suitable for utilization in internal combustion engines, thus making it feasible for heat and power production (Coley, 2008). Anaerobic digestion process produces a by-product, where valuable nutrients from the feedstock can be collected. These remains can be either returned to the land, or used as a fertilizer in agricultural activities (Coley, 2008). In a sense, anaerobic digestion process tries to mimic natural cycles, by reforming waste and side streams into a more applicable form, which can be then utilized to replace fossil materials in energy generation, before returning the elements back to its natural cycle.

Due to the large amount of carbon dioxide produced in aerobic digestion process, biogas is not suitable for all applications immediately. By purifying and upgrading biogas into biomethane, where carbon dioxide and other impurities are largely removed from the gas, the methane level of around 97% is achieved, the gas shares similar composition with natural gas allowing wider range of delivery and end-use applications. When the volume of biomethane is upgraded via compression or liquefication, the space required for the gas is greatly reduced, allowing it to be transported more easily from the base of production to other location (Gasum, 2020). When upgraded and purified, biomethane can also be mixed with natural gas in delivery infrastructure and combustion engines. This means that biomethane does not require a dedicated delivery infrastructure and combustion engines, which greatly enhances the cost-effectiveness in gas delivery and end-use.

Anaerobic digestion is not suitable for all organic materials, but alternative means to produce gaseous fuel are available. Synthetic natural gas[1] (SNG, synthetic biogas, bio-SNG) can be produced from solid biomass via gasification process, where mix of steam and oxygen in a high temperature produce a gaseous fuel (Coley, 2008). In contrast to biogas via anaerobic digestion, SNG consists mostly of hydrogen (47 vol-%) together with carbon dioxide, carbon monoxide and methane, making it also available fuel for combustion engines (Pääkkönen, Aro, Aalto, Konttinen, & Kojo, 2019). Via further processing, practically any hydrocarbon can be synthesized, including biomethane, if deemed necessary (Coley, 2008). If synthesised into methane, the produced gas shares the same characteristic with biomethane, and can be utilized in identical ways with biomethane and natural gas.

Currently, methane can also be collected from landfills directly. In multiple countries, landfill gas actually contributes a significant portion of the total biogas supply (Scarlat et al., 2018). Several countries, including Finland, have imposed a ban of biowaste at landfills, which greatly reduces the potential of landfill gas in the future (Pöyry Management Consulting Oy, 2017).

2.2. Role of biogas in climate change mitigation

In the rise of the climate agenda, biogas has been recognized as a possible contributor in climate change mitigation. Due to its highly flexible nature in both production and utilization (figure 1), and largely available, often uncontested feedstock, biogas may serve climate efforts through multiple ways.

On the production side, biogas production has number of options and practical applications. Most often biogas is produced out of biowaste, which originates from industry or households. By utilizing anaerobic digestion process here, biogas production reduces methane emissions, which would occur in case biological waste ended up in a landfill. Similarly, when producing biogas from cattle manure, the initial setup reduces emissions in handling of manure in farms, as a contained storage, required for manure in biogas production, reduces the methane slips compared to a traditional open-top storage (Winquist, Luostarinen, Kässi, Pyykkönen, & Regina, 2015). Alternatively, manure can be transported

[1] Synthetic gas refers to all gaseous fuels that are produced via gasification process. Hence, not all synthetic gas is renewable or share same composition with natural gas. However, in this study, the scale of terms refer to gaseous fuels, which are produced from biomass via gasification process, and are thus used in an interchangeable manner.

to an industrial scale digester, which has the same reducing effect in methane slips, provided that the storage is emptied, and manure transported to the digester in regular intervals.

Vast majority of the overall biogas potential consists of field crops (Capodaglio et al., 2016). This includes residues and side streams resulting from agricultural activities as well as dedicated energy crops, planted and harvested solely for energy production purposes. In the United States and Central Europe, dedicated energy crops have gained high attention due to appealing subsidy systems established for biogas production, especially in a situation where profitability of food production remains low (Edwards, Othman, & Burn, 2015). However, the total climate effect of energy crops is currently highly disputed, because of their potential to contribute in direct and in-direct land use change effects (Lal, Ranjan, Wolde, Burli, & Blumberg, 2017). Crop-based side streams and residues are not under same level of scrutiny and are classified as 2nd generation biofuels due to not competing directly with food production.

As noted earlier, biogas can be transported via multiple means. The most utilized application is a natural gas pipeline network, which allows for easy and cost-effective mean to transport biomethane utilizing the existing infrastructure. As biomethane shares the same chemical composition with natural gas, mixing of natural gas and biomethane is technically feasible, provided that the methane volume of biomethane is maintained at 97-98% (Coley, 2008). Transportation via pipeline is often considered to be without additional greenhouse gas (GHG) emissions, if the required systems are already in place. Alternatively, biogas can be transported via pressurized tanks on road vehicles or marine vessels. The climate effect of these operations is highly dependent on the vehicle used and whether the gas is compressed (CBG) or liquefied (LBG).

In end use, the GHG reduction from biogas is highly dependent on three interlinked factors: 1) the life cycle emissions from selected biogas operations, 2) provided energy services (heat, power, cooling, vehicle fuel) 3) the system it substitutes (coal, oil, nuclear etc.) (Rehl & Müller, 2013). When compared over the whole life cycle of biogas production (excluding the fuel substitution), combined heat, power and cooling generation and upgrading biogas to biomethane have resulted in the lowest aggregate emissions over their whole life cycle. This is due to the high efficiencies of these operations, which allows larger portions of the generated heat and chemical energy to be effectively used (Poeschl, Ward, & Owende, 2012).

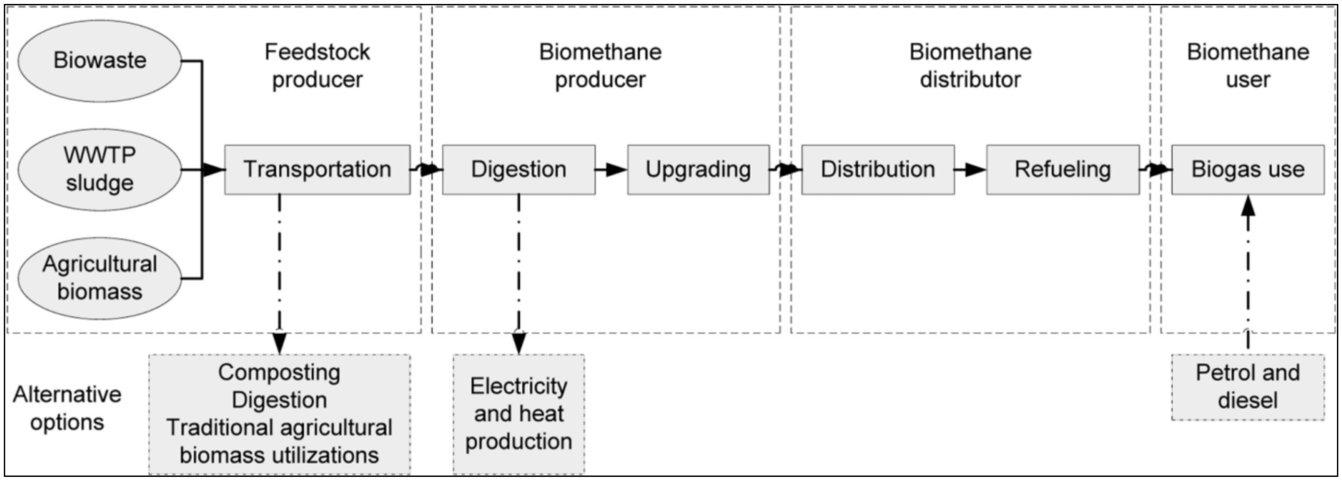

Figure 1. Biogas distribution and utilization chain. (Uusitalo et al., 2015)

When substitution of the reference system is included in addition to the life cycle emissions, evaluating the actual climate affect became vastly more difficult (Rehl & Müller, 2013). Most evident of this dilemma is the use of biogas in electricity generation, where substituting coal-based electricity yields higher GHG reductions compared to a situation, where biogas is used to substitute nuclear production. In general, national energy mix, role of exported and imported energy and national demand of energy have great impact on the climate effect of biogas usage. As the national energy mix varies greatly between selected countries, one cannot expect to get a similar GHG reduction from biogas-based electricity generation in Finland as they would get in Belgium or Spain. In the case of transport and heat production, these problems are not as apparent. Heat production is often highly localized and even the largest applications, district heating systems, do not extend over certain geographical areas. Biogas based heat production is regarded highly attractive option as it is often simplest of utilization pathways, but often does not yield similar reduction in GHG emissions, as when substituting fossil fuels in transportation.

In transportation, a selection of certain few fuels is utilized on a global scale, thus allowing for easier comparison of GHG effect between fuels. Substituting fossil fuels in road and marine transportation has gained increased attention due to a narrow selection of other renewable alternatives and high climate change mitigation potential (K. A. Lyng & Brekke, 2019). Pääkkönen et al. (2019) concluded that almost half of the GHG emissions from Finnish heavy-duty transportation could be offset, if all available biogas could be enabled. However, lack of required infrastructure, insufficient supply and demand as well as poor profitability and investment environment have hindered progression in several countries (Olsson & Fallde, 2015; Pääkkönen et al., 2019).

The total emission reduction is also dependent on the methane slips throughout the value chain, including production, transport and utilization (Hagos & Ahlgren, 2018). Methane is the main component of biogas, and has 23 times higher heating value in the atmosphere compared to carbon dioxide (Coley, 2008). Therefore, even small methane leakages throughout the utilization chain could neutralize the GHG reduction achieved from using biogas to substitute fossil fuels. In a well-to-wheel analysis it has been estimated that in transport usage, 1% increase in the methane slip is able to offset almost half the GHG reduction vis-à-vis a fossil alternative. Therefore, managing the methane slips to the lowest possible level is crucial, especially when utilizing biogas in a system, which requires prolonged bunkering and transporting biogas over distances (Hagos & Ahlgren, 2018). For the same reason it is often hard to estimate the GHG reduction when comparing gaseous fuels over their whole life cycle, and estimations rely heavily on the underlying assumptions and system boundaries used during calculations (K. A. Lyng & Brekke, 2019).

2.3. Biogas and Finnish energy regime

2.3.1. Potential of biogas

There are multiple estimations regarding the energy potential of biogas in Finland. When measured as potential energy, technical estimations vary on a wide range of 14–95 TWh annually (Asplund, Korppi-Tommola, & Helynen, 2005; Lampinen, 2003; Marttinen, Luostarinen, Winquist, & Timonen, 2015; Tähti & Rintala, 2010). More recent studies by Tähti & Rintala (2010) and Marttinen et al. (2015) estimate this potential to be around 24–25 TWh annually. Almost three-quarters of this amount consists of crop biomasses from agriculture. Of the remaining potential, half consists of cattle manure, whereas the other half is a collection of industrial waste, municipal biowaste and wastewater sludge. Considering limitations in location and collecting of this technical potential, Tähti & Rintala estimate the annual techno-economical potential to be 9,2 TWh, with high limitations to the potential of manure (technical 3,4 TWh; techno-economical 1,4 TWh) and crop biomasses (technical 17,8 TWh; techno-economical 5,8 TWh). Even with such a difference between technical and techno-economical potential, the potential of domestic and renewable energy resource, which is also free from competition, is considerable. Marttinen et al. (2015) estimate a slightly higher techno-economical potential of 10 TWh annually. Additional 3,5 TWh/a could be generated from forest biomasses via gasification process to produce synthetic biogas (Pääkkönen et al., 2019). However, this potential is mainly located in the highly forested regions in Northern and Eastern Finland, and might become under competition by forest industry (Aro et al., 2018).

2.3.2. Developments in biogas field

Development of the Finnish biogas field is well documented in the Finnish biogas registry (M. Huttunen, Kuittinen, & Lampinen, 2018). Historically, the production of biogas rose steadily from mid-90’s until 2005, from whereon the production has remained somewhat stagnated (see figure 2). Significant amount of the gas has originated from landfills, where methane is captured from decomposing organic material. Landfill gas has been on a decline after the 2010, but still contributes almost 40% of the overall biogas production in 2017. On the contrast, commercial co-digestion plants, utilizing mostly commercial biowaste, have gained a rapid rise from 2010. Landfills and co-digestion plants therefore play the major role in the biogas production, contributing over 70% of the methane production. Role of other plant types is noteworthy, but somewhat limited. While wastewater treatment plants contribute around 20% of the biogas production, techno-economic methane potential of wastewater is estimated to be almost reached in Finland, so development here seems unlikely (Pöyry Management Consulting Oy, 2017).

While the number of farm-scale digesters has risen during the last decade, their impact on the overall picture is still less than 1% of the overall production. It is noteworthy to mention, that amount of biogas actually utilized in energy services does not follow identical pattern. Use of biogas remained rather low until a hike in 2005, and has risen with a moderate speed after. The difference between biogas produced and utilized is due to flaring, which occurs for unsold surplus.

To summarize, Finnish biogas resources have remained highly unutilized, and energy amount equal only to 640 GWh was generated from this potential in 2016 (M. Huttunen et al., 2018). This amount can be regarded rather low compared to total energy consumption in Finland, which was 378 TWh in the same year (Official Statistics of Finland (OSF), 2016).

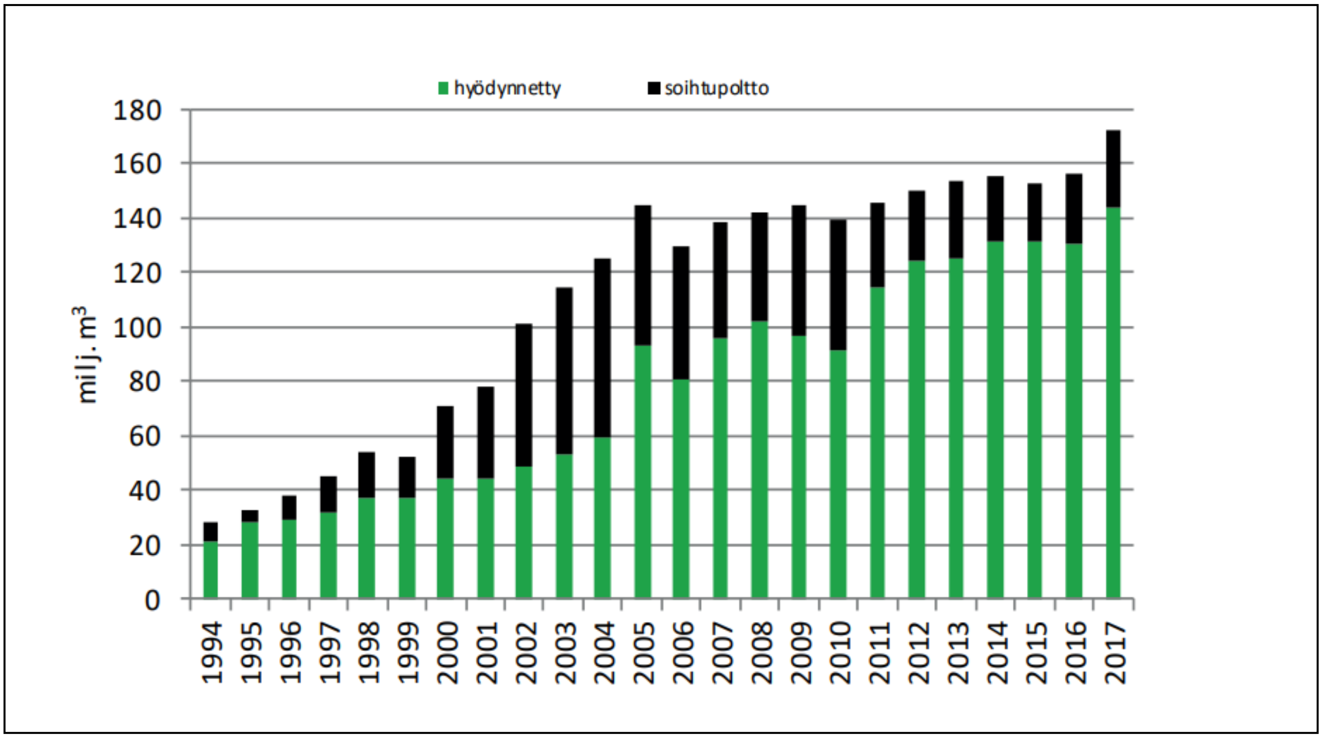

Figure 2. Development of biogas production in Finland from 1994 to 2017. Green bars portray the utilized biogas, whereas black bars indicate the amount of biogas, which was eventually burned in a flare. (M. Huttunen et al., 2018).

2.3.3. Energy regime in Finland

Formulation of the Finnish socio-technical regime has remained largely understudied. However, some efforts have been made to conceptualize trends in Finnish energy policy. Ruostetsaari (2010) describes Finnish policy-making in energy-related issues as highly exclusive. Policy formulation is done in collaboration with politicians, government officials, major industrial actors and representatives of the biggest interest groups. This group of central actors is referred as the *energy elite*[2] (Ruostetsaari, 2010, p. 35), and their mutual interaction is highly lacking in transparency. Energy elite has mostly been favorable towards bio and nuclear energy, while new renewables have mostly been collectively seen as expensive, inefficient and possibly even harmful for the Finnish energy system (Haukkala, 2018).

Result of this political lock-in is a major hindering factor for new renewables, as major changes in the legislative system, energy infrastructure, policial attitude, and decision-making processes would be

[2] Fin. *energiaeliitti*

most likely needed (Haukkala, 2015). Pressure from climate change and increased regulation and agenda-setting from EU level have forced Finnish policymakers to adopt new methods in forming energy policy, but attention is given mostly to wooden biomasses in heat and power production as well as liquid biofuels in transportation (Aro et al., 2018; Toivanen et al., 2019).

2.4. Literature review

Much of the literature on Finnish biogas field focuses on methane yields and accumulated GHG reduction by using various feedstock in Finnish conditions (Laasasenaho, Lensu, & Rintala, 2016; Seppälä, Laine, & Rintala, 2013; Seppälä, Paavola, Lehtomäki, & Rintala, 2009), or technical solutions when it comes finding suitable sites for biomass plants (Höhn, Lehtonen, Rasi, & Rintala, 2014). A limited amount of earlier research has been done on the historical policy development in the Finnish biogas field.

S. Huttunen et al. (2014) studied contemporary policy formulation from the perspective of technological innovation system by combining interviews with policy analysis. The authors found that biogas related policymaking was done independently in various sectors, with domain-specific instruments. This diffusion in policymaking, together with policies cumulating gradually over time, found to be causing incoherence between officially stated policy goals and established set of policy instruments, meant to promote them. Similar notions were found few years later by (Winquist et al., 2019), who mapped potential barriers within the Finnish biogas field through concept of sustainability product. Biogas field in Finland was found to be underdeveloped and somewhat poorly understood. The key policy documents were found to include encouraging, yet reserved framing on the future of biogas, as it was mostly addressed in the terms of energy and potential GHG reductions. Lyytimäki, Nygrén, Pulkka, Rantala, and Society (2018) approached the topic by analysing media coverage of biogas in Finnish newspapers. Exposure in the media was found lacking in the beginning of 2000s, before gaining a rapid hike and stabilizing afterwards. Most often, biogas was mentioned in positive framing with strong future orientation, but mostly as a secondary topic in a broader discussion about renewable energy.

Multiple case studies in Sweden have also demonstrated the importance of politics when promoting biogas on both national and local level (Ammenberg et al., 2018; Larsson, Grönkvist, & Alvfors, 2016). Especially important was the role of policy instruments in use, the linkage of these instruments to the promoted policy targets, and how of a predictable and stable policy landscape they generate. A case study conducted in Sweden found that the low predictability of Swedish policy instruments affects greatly to the stability of policy landscape and thus judgement of the investors in biogas industry (Lönnqvist et al., 2017). Even though Sweden is often considered to be one of the frontrunners in the biogas field, and number policy instruments have been introduced since 1970s, their reach and time in effect have been rather limited (Larsson et al., 2016). While multiple policy tools at different operating levels and stages of development are often required to promote a niche innovation, overlapping policy frames and measures resulted in a complex system of multiple instruments from different policy domains with a different timeframes in mind (Ammenberg et al., 2018). Thus, it rendered the playmaking field rather unpredictable and difficult to operate in. As Lönnqvist notes, "more important than the exact design of the policy instrument is that the support is substantial and predictable" (Lönnqvist et al., 2017, p. 449).

Studies are also available, focusing on use of biomethane in the transport sector. Uusitalo, Soukka, Horttanainen, Niskanen, and Havukainen (2013) found transport sector to be a promising field for increased biogas usage with large reduction of GHG emissions. Pääkkönen et al. (2019) came to a similar conclusion while exploring possibility to substitute fossil fuels in Finnish heavy-duty transport fleet. However, lack of a biogas specific strategy, poorly coordinated policy instruments and uncertain business models were argued to be main barriers for the development of biogas field. Finally, Uusitalo et al. (2015) found economic feasibility of biogas production greatly bottlenecking the development. The authors suggested that economic incentives and other policy instruments in both production and end-use of biogas value chain are most like needed, if biogas was to gain momentum in the transport sector. Larsson, Grönkvist, & Alvfors (2016) found that a broad variety of long term subsidies was needed to enable biomethane in the Swedish transport sector. Authors also note that local cooperation of actors from both the public and private sector was vital for biogas ecosystems to be successful.

Economic feasibility of biogas production has been studied on the international level as well as domestically in Finland, with national realities in mind. In Sweden, estimations regarding biogas production have been made by Lantz (2012). In Finland, the economics of farm-scale biogas production was studied by Winquist et al. (2015), who conclude that biogas production can be feasible even under current policies, provided that all of the produced biogas could be utilized on site, or sold. For production in larger decentralized units, estimations were provided by Pöyry Management

Consulting Oy (2017) on request of the Prime Minister's office. Results show that commercialized AD plants are heavily dependent on gate fees, which they receive from sorting biowaste before AD process. Economic performance could be improved, if biogas could be upgraded and sold as biomethane to the transport sector (ibid).

For agricultural sector, biogas production is found to be a way to enhance rural development (Capodaglio et al., 2016), especially to improve economic condition of farms, which are increasingly facing poor economic conditions (Natural Resources Institute Finland, 2019). Additionally, use of digestate and biofertilizers from biogas production could offset mineral fertilizers in agricultural activities, and thus close depleting mineral cycles (Mutikainen et al., 2016). From the perspective of public planning on the municipal level, ambition to engage with biogas systems is often tied to assumed environmental benefits from enhanced treatment of biowaste and agricultural residues, as well as to opportunities in local economic growth. However, poor economic feasibility greatly hinders the development of farm-scale biogas production (Lantz, 2012).

3. THEORETICAL FRAMEWORK

This chapter explains the framework for the study. Multi-level perspective on system transition is described, followed by notions of state behaviour made by neoclassical realists from the international relations field. Theory synthesis is then constructed to give insight on state behaviour in system transition, by positioning state as an actor in multi-level perspective framework. Finally, limitations of the constructed theory synthesis are briefly discussed.

3.1. Theoretical foundations

3.1.1. Multi-level perspective on system transition

Multi-level perspective (MLP) (F. W. Geels, 2004, 2014; Grin, Rotmans, & Schot, 2010) is a medium-range theory often used to study energy transitions. Multi-level perspective pays attention to development and interplay of three analytical levels: 1) socio-technical landscape 2) socio-technical regime, and 3) niche-level. Socio-technical landscape is understood as exogenous developments (such as climate change, wars), which affect developments on other levels, but itself develops largely independently from other levels. Socio-technical regime refers to a stabilized system of markets, policies, industry, institutions and culture, which is held together by mutual dependencies, lock in mechanisms and shared narratives. Regime acts as the equilibrium of the socio-technical system, which resists pressure from landscape developments as well as from niche level to maintain stability. Stability in the regime is dynamic, meaning that regime composes of multiple ongoing processes, which maintain inertia around the equilibrium. Niches, on the other hand, are small regime-like sub-systems, which seek to establish themselves as part of the regime. Niches often form outside of the dominant regime, where they compete against other niche innovations in terms of investment, exposure and alliances. When a niche innovation has gained enough momentum to break out of the protective space and to contest elements of the dominant regime, it is referred as an empowered niche (Raven, Kern, Verhees, & Smith, 2016). While niches often form around certain technological substitutes, niches should not be considered only in the terms of technological innovation (Grin et al., 2010). Similar to the socio-technical regime, niche innovation should be considered as an internally coherent way of thinking, which may include elements of new business models, promotion of new technology, new coalitions between actors and so forth. According to MLP, key to understand transitions lies in interaction and alignment of these levels, where empowered niche innovations seek to penetrate into destabilized regime level, and establish themselves as part of it. Reorientation in the regime occurs when a niche is able to penetrate a destabilized regime through a window of opportunity, which require suitable alignment of the three levels.

While MLP has proven to be an effective framework to study energy transitions, it is often criticized for only capturing frozen frames of a transition, without providing applicable tools to analyze a societal transition as a whole. Moreover, MLP has been regarded too niche focused, where emergence and cascade of green innovation take the primary focus. Especially criticized is, the poor attention given to politics and power, which are generally situated as static and ambiguous elements withing the dominant regime (Avelino et al., 2016; Meadowcroft, 2011).

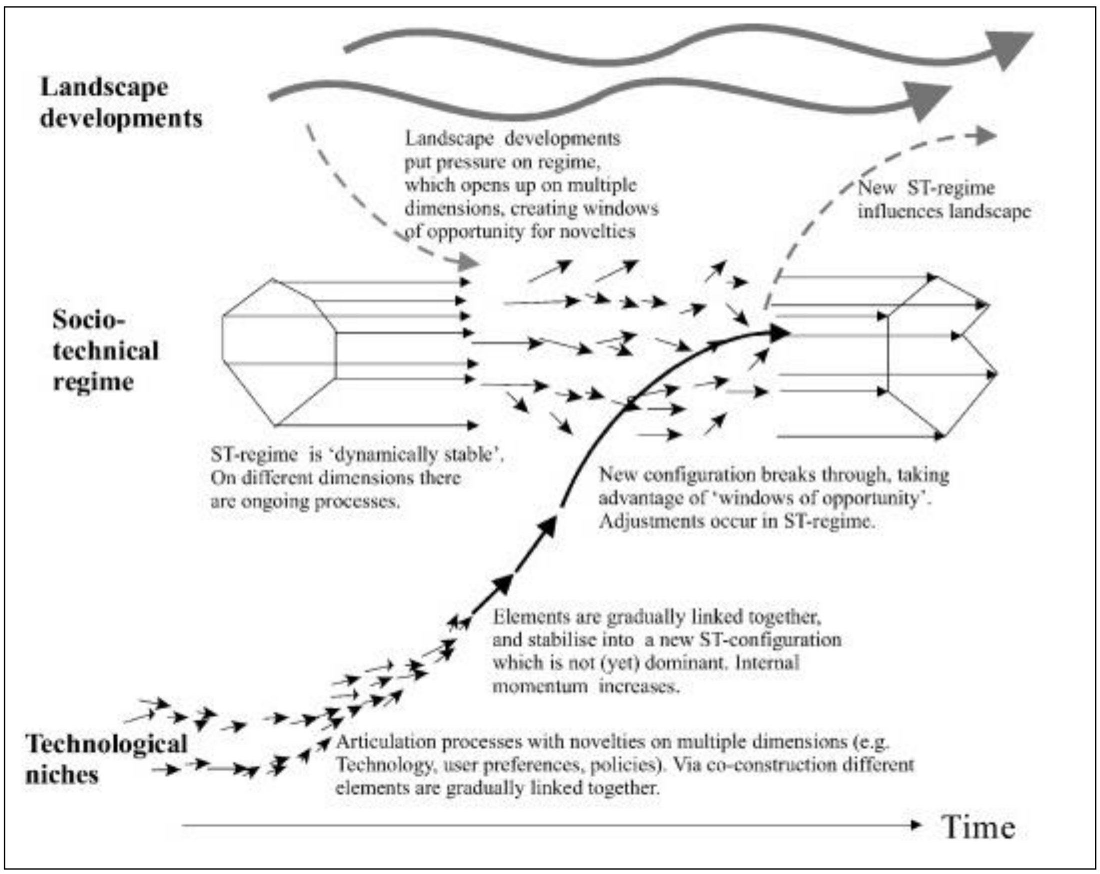

Figure 3. Multi-level perspective on system innovations. (F. W. Geels, 2004)

Later research has provided more detailed discussion on the role of politics and state actor in that sense. F. W. Geels (2014) approaches the role of state from a regime-centric perspective. While political forces are now given more active role within the regime, they are still suggested to act in collaboration with industry actors and actively contributing to the regime resistance, which hinders the reorientation in the energy system. Avelino (2016) finds the role of state highly influential in sustainability transitions, and the position adopted by the state being strongly intertwined to historical and spatial contexts. Langhelle, Meadowcroft, and Rosenbloom (2019) argue that state acts as a central apparatus through which parliamentary forces are able to influence a transition. In a similar manner, Meadowcroft finds the role of state important as, every transition requires changes, which can only be "engineered through political processes, and legitimised and enforced through the institutions of the state" (Meadowcroft, 2011, p. 70).

Thus, the role of state is central in sustainability transition. State can either initiate, amplify or resist the transition efforts, but state's position in the matter is greatly influenced by the context in which the transition occurs. In order to observe state's behavior in transition, understanding state's perception of the context is crucial. To provide more understanding on how the context and state's perception of it influence the position state adopts, this study borrows notions of state behavior from neoclassical realism theory.

3.1.2. State behavior in neoclassical realism

Putnam (1988) famously introduced the idea of a two-level game in international relations, where states conduct foreign diplomacy and domestic policy simultaneously, facing strategic opportunities and dilemmas arising from this cross-pressure. While Putnam's two-level game is mostly focused on negotiation strategies, it still highlights the agency and meditative role of central decision makers in the cross-pressure of global developments and domestic regime. Further connection between global and domestic policies have been established scholars of neoclassical realism in the IR field.

Unlike more mainstream IR theories (Nye, 1988; Waltz, 1979), neoclassical realism (Lobell, Ripsman, & Taliaferro, 2009) focuses on the interplay between international and domestic policy domains. While accepting the notion of neorealism, which suggests seeking for survival being the ultimate motivation of a state action, and power as a mean to accomplish it, neoclassical realists find attributes of a domestic system as a key variable to explain interactions in foreign policy. Stimulus for a policy action is suggested to come from changes in the international system, after which it "passes through the prism of the state, which perceives them and responds to them within the institution constraints of its unique domestic circumstances" (Lobell et al., 2009, p. 31). In other words, national attributes, such as political system, actor coalitions, available material resources, demography and civil society limit the possible courses of action. For this reason, states seek to shape the domestic system into a composition, which allows extraction of domestic power potential, bound to a nation's attributes. As Cesnakas (2010, p. 48) summarizes: "neoclassical realism is a theory where domestic variables interact with systemic forces to keep parsimony". Overall, neoclassical realism situates domestic system as a national modifier, which steers state's options to harvest national power in the struggle for survival. State seeks to mediate developments in both global and domestic domains simultaneously to find an optimal set of conditions, which allows maximizing state power.

In international relations theory, power is approached as capability, or potential for action, which is measured often in military strength (Waltz, 1979). It is understood as a fundamental meter of capacity, which is used to measure and compare capabilities between nations. Power is immaterial, yet it is often measured as material resources. Power is also interchangeable, making it possible to transform economic or demographic power into military power and *vice versa*. Maybe a best example of this changeability can be found from the second world war, where total war pushed nations across the globe to harness their economic, demographical and industrial power for military effort. Same logic can be found in energy field, as power from energy resources can be harnessed for same purposes as military power (Smith Stegen, 2011). While state's struggle for survival is not visibly apparent in everyday political debates, neorealist theories suggest that the fundamental goal of policy making can be traced back to this survival, where states are seeking to enhance their chances for survival by increasing their power in relative to other nations.

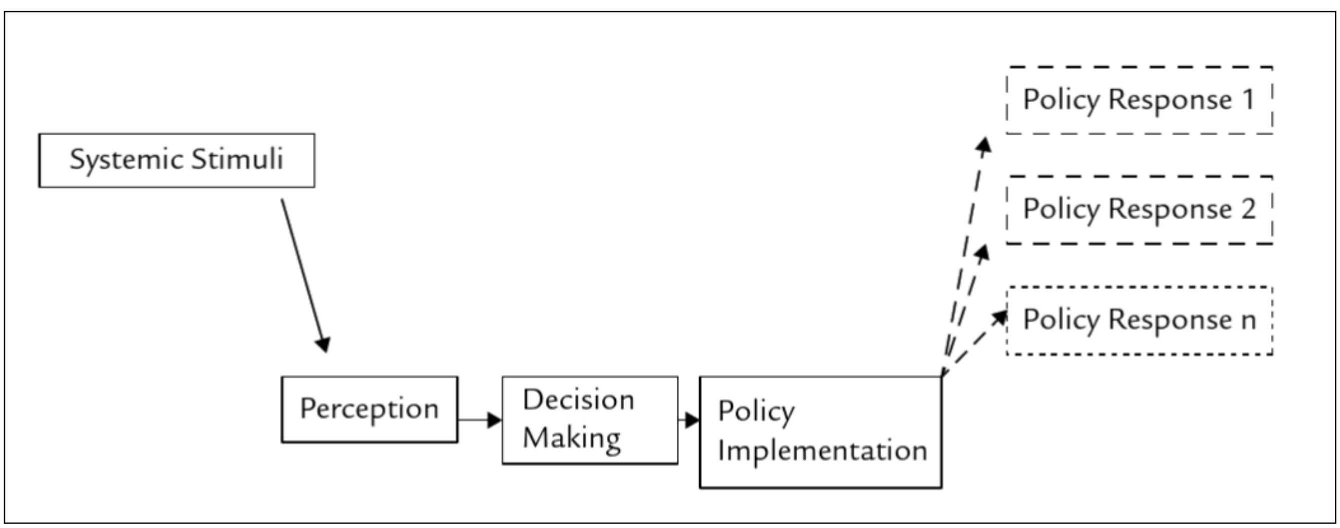

Figure 4. Neoclassical realist model of decision making in foreing policy. (Lobell et al., 2009, p. 31)

Instead of describing state as a monolith institution, neoclassical realists focus their attention to statesmen, who formulate the perception, which a state adopts (Lobell et al., 2009). Statemen can be described as a group of central decision makers, who occupy a vital crossroads between domestic and foreign policy, thus maintaining a monopoly over official state interpretation of global and intergovernmental developments in a national context. Neoclassical realism theory suggests that statemen are rational actions, but their rationale is inherently limited by human constraints (Cesnakas, 2010). These constraints mean that any interpretation is subjective in its essence, resulting that policies are formulated based on these perceptions of the matter (figure 4).

3.2. Introducing state behavior to multi-level perspective

Argument put forward in this thesis is that introducing notions from neoclassical realism allows us to better understand state behavior and motives in a system transition, portrayed in multi-level perspective framework. Neoclassical theory suggests that states treat domestic policy domain as a system through which national power resources are extracted. This domestic domain can be understood as the regime portrayed in MLP theory, composing highly similar interlinked and complex system of actor coalitions, political forces, industrial capabilities and civil society actors. System stimuli, what neoclassical realists suggest originating from changes in the international system, can be considered as developments on the landscape level in MLP, perceived important by central decision makers. This suggest positioning state between landscape and regime levels, while still giving notion to state's status as primarily a regime-centric actor, as MLP generally suggests. Perception, which results from statesmen's subjectivity and other human constraints, is evident in two ways: firstly, in the interpretation of the effects resulting from landscape developments in the given context, and secondly, when evaluating consequences of adjustment in the regime. These perceptions are weighted against one another to find a best suitable formulation for the regime, which is able to extract maximal amount of power in light of the landscape developments.

In relation to the three levels presented in MLP (F. W. Geels, 2004), this process and role of a state actor can be summarized as follows: Firstly, a state, represented by statesmen constantly *observes* developments on the landscape level. These developments are many, but to give few examples in the context of energy policy, this would mean general technical development, new intergovernmental treaties, energy prices and exposure of the climate change agenda. Process of observation is limited by historical developments and formulation of the regime, for selection on what is deemed important is done form a perspective of the dominant regime. This limits the observation, as not all developments are noticed or regarded important in the given policy domain.

Secondly, these developments are then *interpreted* in a national context. Developments observed from the landscape are reflected upon the attributes of a national energy regime to conceptualize the implication the developments on the landscape might have in the context of a national energy system. Interpretation is therefore a process where the perceived landscape developments are given meaning on a national level, which gives a more practical framing on whether the development requires action in the selected policy domain.

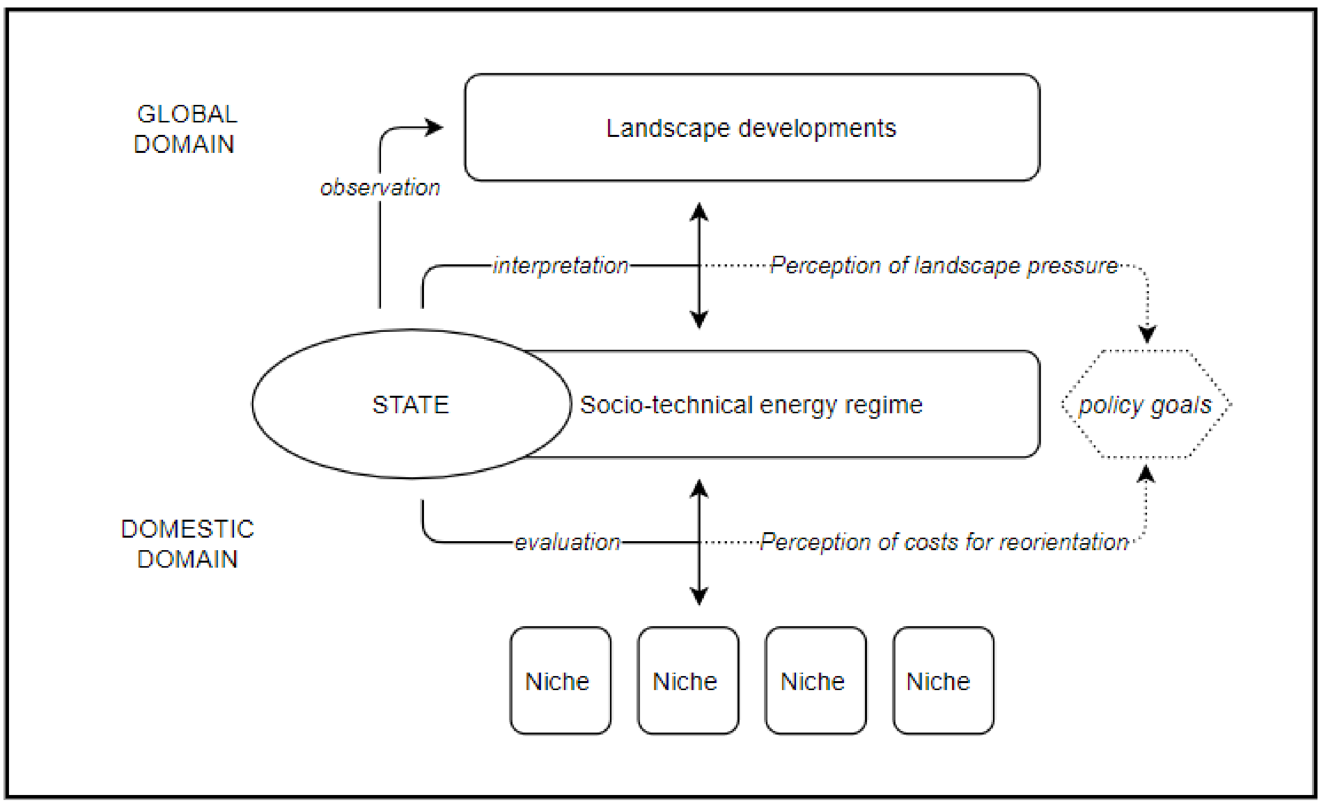

Figure 5. State behavior in relation to analytical levels of multi-level perspective. (Created by author)

Thirdly, if a response for the landscape development is deemed expedient, a state engages in *evaluation* of the regime and possible innovations on niche levels to find an optimal configuration for the regime. When suitable niche innovations are found, they are evaluated against the composition of the dominant regime to see whether a reorientation to a desired direction is deemed feasible. Three key variables play part on whether an adjustment of a regime occurs: 1) severity of the perceived development, 2) strength and fitness of available niche innovations, 3) strength of the dominant regime.[3] Different configurations of the regime, niche level and perceived effects of their adaptation are evaluated against each other as well as versus inaction on the matter.

When reorientation within the regime is deemed appropriate (assumed benefits or evasion of harmful effects outweigh costs involved in reorientation) a state adopts according position and policy goals to reflect this desire for change. If the costs of consequence involved in the reorientation are perceived to outweigh the effects from landscape developments, no action is taken. Fundamental dilemma the central decision makers face is to balance pressure for change from landscape developments in global domain, and consequences for the corresponding realignment in the domestic domain (figure 5).

Situating state into MLP as described above would suggest following things:

1) National energy policy is fundamentally created to realize national energy potential into to the best possible extent. Socio-technical regime is considered as the central apparatus in the process, thus changes in the regime either increase or decrease the state capacity. States seek to shape the regime into a best possible configuration in relation to landscape developments.

2) State is a unique regime actor, which shares a regime-centric perspective on energy affairs, but simultaneously possesses significant amount of agency to support niche innovations and cause destabilization of the regime when deemed appropriate. State's perception is mainly regime-oriented, thus perception of landscape pressure and possible alternatives are often framed in favor for maintaining status quo. However, unlike many incumbents in the regime, state is also active in other policy domains. Changes within other policy landscapes may have great effect on states perception on energy sector. Alteration or coupling of themes in energy domain might cause significant changes in state's perception on energy affairs in both domestic and global domains.

3) State is a cost-benefit maximizer, who advocates for adjustment of the regime, when cost of adjustment is perceived to be lower than the perceived pressure from landscape developments. As state seeks to maximize power gains with minimal cost, state pushes for adjustment of the regime with minimum effort in relative to the perceived power change. If the power change is

[3] This formulation of three key variables is best understood as the alignment of levels, which opens the window of opportunity for a regime adjustment in MLP theory (F. W. Geels, 2004).

> perceived significant, state is more willing to engage in a swift and costly adjustment. Similarly, if an interpretation of the power change is uncertain and affects only in a longer term, a less costly options (or inactivity) is more likely to be selected.[4]

What Geels. et al. (2014) called regime resistance, can be understood as state's reluctance to engage in an adjustment process it sees unfeasible from cost-benefit perspective and as a failure to find an alternative configuration with a reasonable cost of economic and institutional power. In other words, states opt to advocate for maintaining of status quo, if they see no better alternatives. Effects of path dependency and system lock-in, which are central elements in multi-level perspective (F. W. Geels, 2012, 2014) are acknowledged as well, and they affect both policy domains. As statesmen perceive and interpret the global developments closely to a perspective of a regime actor, their observation and interpretation of the development is framed by historical tendencies and trajectories in national energy agenda, similar to historical and spatial contexts noted by Avelino et al. (2016). This causes certain developments to go unnoticed and affects the national narrative on of the developments, deemed important by statesmen. On domestic domain, mutual dependencies and system lock-ins strengthen the domestic energy regime, making reorientation seem more costly, thus reducing the attractiveness of reorientation.

This implies that rather than being a static incumbent actor of the regime, a state plays an active role in both niche and regime levels. While preferring stability in a regime, state is constantly observing, interpreting and evaluating developments on all three levels to find the best possible combination for a national energy regime.

[4] Frank W. Geels et al. (2016) suggest there are four interconnected pathways a transition may take: substitution, transformation, reconfiguration and de-/re-alignment. A state participation is crucial in any of these, but substitution and transformation pathways seem to occur, when pressure from landscape is not perceived imminent or vital by the state, as these pathways are more market-oriented, focusing on layering and gradual change. Reconfiguration, which focuses on new alliances between incumbents and new entrants (niches), might be engaged by a state strongly advocating and empowering certain niches, when landscape developments are deemed to require major adjustments in the regime. In de-/re-alignment, dominant regime collapses under sudden and unexpected pressure shock from landscape. While a state may not start a transition via de-/re-alignment, and regime collapse is often accompanied with major costs for the state, it opens new opportunities to reshape the structure of the regime in its core (re-alignment).

3.3. Limitations of the framework

Adopting a state-centric view on energy transitions provides theoretical notions on the state's position when formulating energy policy. Theoretical framework in this study is supposed to provide perspective in the role of a state in multi-level perspective, not to majorly modify the overall framework. For that it is too simplistic. However, certain shortfalls of the framework should be discussed.

Neoclassical realism was originally developed to increase exploratory power of neorealism in cases, when tools of mainstream theories were found inadequate to explain state behavior in international system (Lobell et al., 2009). It was considered to be highly context dependent, and to be used in extreme cases, where system level analysis proved unfeasible. Theoretical model of neoclassical decision making was only later adopted as a general framework to study state behavior (ibid.). However, neorealism is often criticized for being too broad, as it widens the frame of reference from international system into human perception and domestic policy domain (Cesnakas, 2010). It is rather easy to theorize that domestic and global domains are interlinked, as it is to state that any observation is subjective by nature. Neoclassical realism fails to provide more practical analytical tools for further analysis.

These weaknesses are apparent also in the framework of this study. State's perception is considered to be one of the statesmen as a whole, without analyzing the internal struggles within this collective or the actual composition of it. Moreover, additional analytical tools are required to understand the interpretation and evaluation processes between landscape, regime and niche levels. As for now, they are left mostly as reflections of regime-centric perception, while also noting state's unique role in general cross-sectorial policy making. State's action in various overlapping policy domains, boundaries of these domains, and resulting perception of state's overall position require major refining. Cost of consequence is too ambiguous construct for an in-depth analysis and requires more practical definition and metrics.

The framework places other actors in the domestic domain in a rather static position, where decision making power is centered to the state. While the framework does not suggest that the state alone wields the monopoly on whether changes in energy policy will actually occur, other regime actors in the domestic field are left as ambiguous constraints of the regime, measured mostly as costs of reorientation. Whereas MLP is criticized for being too niche-centric, theoretical framework here implies that stimulus for regime adjustment originates mostly from landscape pressure, leaving niche innovations without agency, as they are mostly waiting for external empowerment and for the window of opportunity to open. Theoretical framework allows niches to emerge to contest the regime first, after which the potential regime adjustment is evaluated against landscape developments to form a policy stance on the matter. However, similar to the regime, niche agency is simplified to being only able to alter the perceived cost of consequence of regime adjustment.

4. METHODOLOGY AND MATERIALS

This research uses means of qualitative content analysis (Hsieh & Shannon, 2016; Schreier, 2012; Tuomi & Sarajärvi, 2009) to describe and analyse contemporary perceptions on biogas in Finnish official policy documents between years 2001 and 2016. The research strategy is abductive (Kovács & Spens, 2005) and theory-guided in its analysis, and leans towards summative content analysis in its methodology, while also borrowing means of conventional data-driven content analysis as part of the research design. The materials of the study are drawn from the five existing Energy and Climate Strategies, National climate road map 2050 and a civil service report on energy policy options, which have set the central guidelines and goals for decision making in Finnish energy policy for the last decades.

4.1. Qualitative content analysis

Qualitative content analysis (QCA) refers to a wide range of methods, which seek to systematically describe meaning within material (Schreier, 2012). It is often considered to be a basic method for qualitative analysis, as it can be practically used to study any data that can be set on a written form (Tuomi & Sarajärvi, 2009). The main goal of qualitative content analysis is to use systematic methods to reorganize the data into a reduced and clear form, without losing any of its information, to a point, where it allows a researcher to answer the selected research questions. Whereas quantitative research is often interested in a set of variables, operationalized and analysed as a set of numbers, the focus of qualitative research is usually more case-specific. Therefore, qualitative research is interested in a more holistic perspective of phenomena and seeks to describe, explore, and understand them in their entirety (Schreier, 2012). The advantages of qualitative content analysis stem from its highly flexible nature as, there are practically infinite number of applications to utilize the methodology (Schreier, 2012). This means that not only is the basic concept of the methodology easy to modify based on the material and research question presented, but it also allows for progressive changes during the process to suit the needs of the research.

Hsieh and Shannon (2016) categorize content analysis into three groups: conventional content analysis, directed content analysis, and summative content analysis. In conventional content analysis, coding is conducted based on the data analysis and is supposed to act mostly independently from the existing literature. A study is likely to be observative, as the lack of existing research allows coding to emerge organically from the materials at hand. On the contrast, directed content analysis draws its coding and definitions from a defined theoretical framework or relevant research findings. In directed content analysis, coding grid is formed mostly before that coding process. Summative content analysis stands somewhere in the middle of the two, as it encourages defining of certain keywords prior the coding in order to lower the risk for missing certain key categories, due to lack of larger context – something that conventional content analysis is sometimes blamed of. Regardless, summative content analysis is still more data-driven than directed content analysis, as it urges to explore phenomena mostly without the limitations and boundaries of the existing literature.

Similar grouping is presented by Tuomi and Sarajärvi (2009). By their categorization, qualitative content analysis (and qualitative research in general) can be divided into data-driven analysis, theory-guided analysis and theory-driven analysis. Similar to conventional analysis, data-driven analysis is mostly interested in the data itself, and seeks to explore new theoretical notions emerging from the analysis. Accordingly, theory-oriented analysis is closely related to directed analysis, as it forms its definitions and categorizations based on earlier literature. The role of theory-oriented analysis is more to test, complement or demonstrate existing theoretical frameworks. As is the case with summative analysis, a theory-guided analysis recognizes the role of existing literature during coding and analysis, but the role of existing theories is more guiding, instead of bounding. Theory-guided analysis is rarely used to test existing theories or to create a new one from the ground as, the main purpose is to describe or explain a specific research question at hand (Valli & Aaltola, 2015) Most importantly, in theory-guided analysis, data is analyzed independently from theories, but the results from the analysis are drawn based on the existing literature (ibid.). Therefore, theory-guided analysis is especially suitable for research questions, where describing and explaining a phenomenon in a larger context is desirable, but neither developing a new theory nor testing an existing one does not serve the purpose of the study.

In a general terms, conventional content analysis tends to stay close to the data and emphasizes data-driven approached and applies more inductive logic in its analysis (Tuomi & Sarajärvi, 2009). Conventional content analysis of often highly context specific, and therefore requires a careful assessment on how applicable and transferrable the results could be in other instances. However, conventional analysis allows the researched to suit the needs of a specific case more practically than other forms of content analysis, with the cost of generalizability. Directed content analysis tends to draw the starting point from the existing theories and uses deductive logic in its reasoning. This allows for a high validation of the coding grid and a string starting point for the analysis, but risks to miss case specific details on the subject at hand. Again, summative content analysis stands somewhere in the middle ground, combining aspects of both and often applying pragmatic use of existing research. Summative content analysis often employs abductive reasoning, where inductive data-driven discoveries and deductive notions from existing literature are combined in a pragmatic manner. Abductive reasoning does not try to build logical models through induction or deduction, but seeks to explore possible explanations in-depth in relation to the research question at hand (Kovács & Spens, 2005). Use of abductive reasoning places high stress on validity of the overall study, because combining of inductive and deductive arguments as well as data-driven and theory-oriented explanations may easily seem confusing or even expedient. Applicability and generalizability of the research results and conclusions are also to be carefully assessed, when applying abductive reasoning (Kovács & Spens, 2005).

It should be noted that here is no explicit answer on when directed or conventional content analysis transforms into a summative content analysis (Hsieh & Shannon, 2016). As the coding grid and the formulation of the coded units are expected to be on a constant flux during the coding process and analysis, only the starting point of the analysis can be accurately described.

4.2. Validity and reliability

Validity and reliability are key concepts in any research. Validity and reliability originally come from the naturalistic tradition of research, and are formulated with quantitative research in mind. They form the basis for generating scientific knowledge by addressing functionality of data, methods and reasoning within a research process.

According to SAGE Handbook of Applied Social Research Methods, "*validity* refers to the likelihood that what is detected is, in fact, the effect of interest" (Bickman & Rog, 2008, p. 44). In other words, a research is valid to the extent it actually measures the phenomenon it is supposed to measure (Schreier, 2012). Validity in terms of qualitative research can be also understood in a broader sense, where it "refers to the entire study and soundness of the findings and conclusions" (Schreier, 2012, p. 27). Validity in its broader sense naturally includes use of sound and purposeful methods to measure constructs in your study, but also links reliability as an integral part in strengthening the overall validity of a study. *Reliability* refers to absence of errors in the data and in the findings of the study (Schreier, 2012). While validity and reliability are interested in different aspects of research, their relation is often interlinked in qualitative research: increase in validity often increases reliability of the study and vice versa. However, this is not to say that a study with a high degree of validity could not be poor in its reliability.

In qualitative analysis, validity often takes priority over objectiveness and reliability as a criterion when evaluating soundness, consistency and quality of a study. In a narrow sense, validity is ensured by providing sound methods and reasoning during different parts of the research process (Schreier, 2012). As the primary analytical tool in a data-driven content analysis is the coding grid and the coding itself, special emphasis should be given for ensuring validity of the two. This may be done by acknowledging the position of the researched as a subjective, constantly interpretive and reflective actor. In the simplest application, validity can be strengthened by carefully describing the position of a researcher to allow transparent interpretation for a reader to understand, how this position might affect the coding, and thus the results.

Additionally, validity of a coding grid and the overall coding process can be enhanced by describing the reasoning of choices made during an analysis (Tuomi & Sarajärvi, 2009). The aim here is to ensure that a researcher is constantly attacking and critically evaluating the strength of the coding grid, by trying to find alternative categories for coded units, and by trying to find different formulation for the coding grid altogether. Approaching validity this way, content analysis turns into an iterative process, where there is a constant flux in the formulation of a coding grid and the process of coding itself. This iterative process is only finalized when a stable lock-in is found between a coding grid and the coded units, which strengthens the validity of the research process as a whole. Observations during these iterative rounds should be carefully described, in order to provide a transparent read onto how the final setup of categories was formulated and how the coded units were situated within them.

This leads to an interesting problem when it comes to reliability. Above, it is established that the process of coding is highly subjective in nature. This effectively means that errors in the research do not appear in the same sense as they do in quantitative research, where they can be rooted out via repetition of a same research setting (Schreier, 2012). Therefore, addressing reliability through cohesion of results over repetitive studies is hardly ever feasible in qualitative research.

The underlying essence of reliability lies in a question: ”What should be included in a research report in order it to be reliable?” (Tuomi & Sarajärvi, 2009, p. 68). There are multiple ways to answer this question when conducting qualitative research: On one hand, some scholars reject the notion of reliability altogether. They find this kind of question setting to be arbitrary and misleading due to the subjective and context-dependant nature of qualitative research. This is especially true in social sciences, where the subject of research – human behaviour and interaction – does not appear as static (Cypress, 2017). Moreover, as qualitative research is often highly personal and in-depth in its core, the means and criterion, which ensure reliability in quantitative research (such as repeatability), are not applicable in a same sense (Schreier, 2012).

On the other hand, some scholars argue that reliability criteria should be adjusted for qualitative research, after which it can be addressed and satisfied. Instead of addressing reliability through the concepts of repeatability and systemacy of results across repeated studies, reliability of qualitative research could be found in the internal systemacy of the research process instead (Schreier, 2012). Tuomi and Sarajärvi (2009) emphasise the overall consistency of the study as important for ensuring reliability as completing a set of reliability questions, which is often the practice in quantitative research. The role of a research report is not to ensure repeatability in results, but to provide a guide to the research by providing a transparent and clear description of the data collection process and the analysis that follows.

It is quite safe to say that there is no one universal way to address validity and reliability when conducting qualitative content analysis. Instead, they can be considered as interlinked concepts where the utility of reliability, and applications to achieve it, can only be evaluated in the context of the research. In this study, reliability is strengthened alongside validity by providing a detailed and transparent explanations on the choices made during the research process. Reliability of the study does not lie in the repetition of results, but in the systemacy of the data collection and transparency of the process itself, which in turn enhances the overall validity of the entire study.

4.3. Application of QCA in this study

The application of content analysis in this study builds upon Tuomi and Sarajärvi (2009) and Schreier (2012). The research can be considered summative and theory-guided: the existence of earlier literature and theoretical framework is noted and thus evident during the coding process as well as in the discussion section. Otherwise, the practical coding process itself follows guidelines for data-driven analysis presented by Tuomi and Sarajärvi (2009, pp. 109-113). After setting the initial keywords and points of focus, the analysis is conducted as close to the data as possible. This effectively means that the coding grid, codes and subcategories emerge from the data during the analysis. Means of theory-guided analysis are apparent when forming the head categories, where the allocation of subcategories into head categories was influenced by existing literature in contrast to a data-driven manner.

In this study, the content analysis conducted in several parts:

Selecting the research question acts as an integral part for any QCA application. The research question effectively specifies, which aspects of the data are to be included in the analysis, and which are to be left out (Schreier, 2012). It is often the case that number of new interesting issues emerge from the data during the analysis. A good research question is clear and unambiguous, which keeps the analysis focused in the selected topic in the flood of new and interesting topics, which might steer the research away from its original purpose unintentionally (Tuomi & Sarajärvi, 2009). *Selection of relevant research material* is interlinked with selecting the research question, especially if the material is not collected directly for the research purposes (f.e. interviews and questionnaires). Not all material is able to answer the specific research question and thus finding suitable material requires preparation. Reasoning for the chosen material must be sound.

Evaluating contents of the documents is done prior to the main coding phase. The research material is studied and revised in order to generate a general idea of the contents at hand, and to better distinguish parts that are relevant to the study (Tuomi & Sarajärvi, 2009). Thereafter, the material is evaluated and *divided* into parts that are to be included in the coding process and to parts that are to be rejected from further analysis (Schreier, 2012). The material is selected using a set of *keywords*, which allow to pin-point relevant parts of the text to be included in the analysis. The selection of keywords is done based on the researcher's previous understanding of the Finnish biogas field, and supplemented by observations made during the document evaluation.

The analysis is continued with *segmentation* of the material. After the initial selection is completed, the selected material translated into English and set to the coding grid. Material is then further divided into smaller units, called *statements*. Statements may take form of a single sentence or a set of multiple sentences, provided that they constitute around the same theme or idea. In certain cases, adjustments to the original text are required due to the scattering of the same theme over a longer part of a text. Here, clear and systematic rules need to be established to process any exceptions. It is expected that in this point the selected material still includes text, which is not relevant for the study. For example, sentences which are part of a larger body of text, but do not constitute to the statement itself. These texts are naturally removed during the segmentation process, as statements become the primal unit of analysis.

In this study, *reduction*[5] of the material occurs after the segmentation and refers to a process where statements are evaluated more carefully, and the choice of their inclusion to the coding process is addressed. In a data-driven coding, where the codes emerge from the data during the analysis, reduction requires clear rules to which parts of the material are to be included. Certain codes might be already identified during the evaluation, but to err on the side of caution, it is expected that not all codes are found at this stage, in order to keep the process as systematic as possible. Therefore, statements are evaluated based on their expression and dictation, and reflected against the research question.

In the main *coding process*, statements are situated into number of different categories based on themes within the statements. This process begins by distinguishing repetitive themes throughout the statements and marking statements reflecting this theme into a same *subcategory*. New categories are created when a statement cannot be situated in an existing category. After founding a new category, all statements are evaluated against this new division of categories. Similarly, if multiple statements should fit into two categories at the same time, option for combining two categories into one is considered. This means that the process of coding and creating of categories happen simultaneously and are inherently interlinked to each other. The coding process is finalized when all statements can be situated into matching categories, while simultaneously avoiding large number of categories with only few statements within them (Schreier, 2012). Statements in the subcategories are then *labelled* to represent the entirety of statements within this category as accurately as possible.

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[5] Handbooks on content analysis usually use the term *reduction* in a different meaning. Tuomi and Sarajärvi (2009) describe reduction as a process where units of text, resulting from segmentation, are condensed into their key meaning. However, as the statements found during the segmentation process prove to be quite short already, and condensing of statements is already done during the segmentation, this was not deemed necessary in this study. Instead, reduction here implies process of evaluation the statements, which resulted from the segmentation process.

After labelling, the subcategories are formulated into *head categories*. Head categories are formed by combining the subcategories into reasonable and internally logical entities, which provide answers to the research question. Abductive strategy is utilized here to combine data-driven sub-categories and larger political trends from the Finnish context into a cohesive set of head categories.

Finally, the head categories are *described* and interpreted against the research question. The aim is to accurately describe the meaning of the whole range of statements and the entities they form together. The head categories provide a clear and systematic outlook into the perceptions, which have been embedded into the Finnish political documents from 2001 up to 2016. In addition to the contents of head categories, the measures of frequency are examined over the time period, which allows to distinguish possible changes of focus within the documents between different years. Similarly, developments and alterations within the head category are addressed if applicable, to highlight changes in perception within a same theme.

4.4. Research materials

The materials for the research compose of five currently published national energy and climate strategies dating 2001, 2005, 2008, 2013 and 2016 (Ministry of Economic Affairs and Employment, 2001, 2005, 2008, 2013, 2016), a national energy road map to 2050 (Ministry of Economic Affairs and Employment, 2014), and a comprehensive civil service report on energy policy options (Ministry of Economic Affairs and Employment, 2015). These materials are listed as the key documents in the official page for Finnish national energy and climate strategy and are publicly available on the website of Ministry of Economic Affairs and Employment of Finland (MEE) (2020). All documents are written in Finnish. While there exist official and unofficial English translations for some of the documents, not all of them are complete, some including only an abstract and segments of the original content. Therefore, the original Finnish version of a document is used in all instances, for the sake of consistency.

Energy and climate strategies act as the backbone in decision making, where energy and climate goals are established. The first climate energy and climate strategy states the role of the document as follows: “[Strategy] includes the outlines, goals and measures, which the government deems necessary in accomplishing the national goals"[6]. Additionally, the strategies are supposed to act as a "basis for the positions taken by the government, in the negotiations of European Union and in other international context, in addition to national policy planning and decision making"[7]

While the earlier strategies were published in irregular intervals, it has become a tradition that every government revises the strategy once during its term. The role of strategies is not set in the Finnish law, and therefore hold no juridical power. However, governments have strived to harmonize the strategies with their own governmental plans, and with the climate and energy related targets by of the European Union, which gives them central role in matters of energy and climate policy during the term (see f.e. Ministry of Economic Affairs and Employment, 2016). Energy and climate strategies are prepared by the members of the government, which may choose to create a strategy in cooperation with other parliamentary entities. Advice and knowledge by central civil servants from different ministries are utilized in preparation of the strategy. The finalized strategy is presented to the parliament in a form of a report, and these finalized reports form the base of material to this study.

Strategies are often published alongside supplementary appendixes such as technical background papers and scenario appendixes. Their inclusion to the analysis is considered, but eventually rejected. It is expected that the act of leaving certain parts of the background documents unmentioned is a conscious choice, and the contemporary perception of biogas field is better portrayed without these more technical supplementary papers.

Energy and climate road map 2050 is a parliamentary report, which states to act as a "guide on a strategical level, when Finland is seeking to accomplish its long term plan of climate-neutral society"[8]. While the road map restrains from presenting specific measures or promoting certain pathways to achieve the long term goal, it "explores alternatives, recognizes shared conditions across these alternatives and highlights national strengths as well as weaknesses of Finland, which have a major role

[6] "[Strategia] sisältää ne linjaukset, tavoitteet ja toimenpiteet, jotka hallituksen mielestä ovat tarpeen kansallisen tavoitteemme toteuttamiseksi." (MEE, 2001, p. 3; translated by author)

[7] [--] hallituksen kannanottojen [pohjana] sekä Euroopan unionin neuvotteluissa että muissa kansainvälisissä yhteyksissä, sekä kotimaisen politiikan valmistelussa ja päätöksenteossa." (MEE, 2013, p. 7; translated by author)

[8] "[--] strategisen tason ohjeena matkalla kohti Suomen pitkän aikavälin tavoitetta, hiilineutraalia yhteiskuntaa." (MEE, 2014, p. 14; translated by author)

in meeting the GHG reduction goals."[9] As with energy and climate strategies, the road map is created by working group, consisting of ministers with the help of according ministries. While the energy and climate road map considers policy developments in a larger time frame than energy and climate strategies, and differs in its approach to not describe specific methods, it can still be considered a key document in policy planning and energy and climate related decision making. Moreover, it addresses the role of different energy sources in a similar manner and provides context for the later national energy and climate strategies.

Final document to be included in the analysis is *Report on energy policy options*, published in 2015. This report differs from the energy and climate strategies and the energy and climate road map as, it is a report commissioned by the government and created by civil servants. Therefore, it cannot be considered as a political document in a same sense as the previous documents. However, it is listed as a key document, and its role is central in building further energy and climate strategies. As such, it can be considered a key document, which shapes the perception of the policy options in regard to general decision-making and role of different energy sources. Report on energy policy options was created to give more practical outlook to themes presented in the energy and climate roadmap 2050, without proposing certain measures over others. The report mainly focuses on the use of different energy sources and corresponding policy options, especially in the context of the then upcoming Finnish climate law (Finlex, 2015) and the energy and climate package by the European Union (European Comission, 2020).

Other relevant documents, especially the Medium-term Climate Change Plan for 2030 (Ministry of the Environment, 2017) are considered for the analysis, but eventually rejected. The reason being that their approach to the topic is often narrower and heavily measure-oriented, which does not fully reflect the research question, which hopes to catch a more holistic long-reaching themes on perception of biogas in the domain of national energy and climate policy in Finland.

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[9] "[tutkii] erilaisia vaihtoehtoja, tunnistaa kaikille poluille yhteisiä edellytyksiä ja nostaa esiin Suomen kansalliset vahvuudet ja toisaalta myös rajoitteet, joilla on kasvihuonekaasupäästöjen vähentämistavoitteen kannalta erityisen suuri merkitys." (MEE, 2014, p. 14; translated by author)

4.5. Research report

4.5.1. Evaluation of the documents

Before starting the coding, all documents are loaded into pdf-files in their native Finnish forms. Finnish versions are used, for the sake of consistency. After selecting the documents to be included to the research material, keyword biokaasu* (biogas) is used to identify all instances, where biogas is mentioned. In the first round, all instances including the keyword, regardless of the context, text type or other defining features, are included.

During the first round of evaluation, multiple new terms emerge as closely tied with biogas-related paragraphs. After inspecting the notes from the first round and considering the reasonability of introducing new keywords, some adjustments are made to the list of keywords: terms "synteettinen maakaasu" (eng. synthetic natural gas) and the corresponding abbreviation "bio-SNG" are added, since use of these terms is closely tied to parts dealing with biogas. In addition, number of instances where these terms are used, is inspected to be rather high especially in the period of 2013-2015. Later on, three other keywords are included due to them being closely tied with the term biogas: "biometaani" (eng. biomethane[10]), "CBG" (compressed biogas) and "LBG" (liquified biogas). Every time a new keyword is added, all documents are inspected again in order to find more instances with the updated list of keywords. Due to the characteristics of the Finnish language, some keywords had to be cut short in order to find instances, where the keywords are used in different grammatical cases. These cut-outs are marked with * after the keyword.

When the search finds a keyword, the full paragraph including the keyword is added to a coding grid in Microsoft Excel. At this stage, the coding grid includes only the Finnish paragraph, complemented with the name and year of the document. After the iterative search with added keywords is completed, all selected paragraphs are translated into English. The translations were provided by the author and aim to portray to intent and meaning of the original text as much as possible. However, they may not follow the original text in a word-to-word fashion, due to the grammatical differences between Finnish and

[10] It should be highlighted that the keyword "biomethane" is chosen over "methane". Due to the climate theme covered in energy and climate strategies and their appendixes, using of the word methane is consistently found in the context of a greenhouse gas, not as an energy carrier. Therefore, keyword biomethane is found to be more suitable when searching meaningful results in light of the research question.

English. Used keywords are bolded in both excerpts from original text as well as the English translations.

4.5.2. Segmentation and statements

Segmentation of the material is conducted for the paragraphs selected during document evaluation. As the paragraphs selected in the document evaluation vary greatly in their length, segmentation reorganizes the data to a more systematic form, where single analyzable unit only contains one node of information. Here, the aim of segmentation is to divide the chosen paragraphs into single statements, which will act as the primary analytical unit in the analysis later on.

A *statement* refers to an idea or theme, embedded and identified from the selected paragraphs during the analysis. A statement may vary in length and mean of expression, and as multiple statements can be found within a same paragraph, not all of them include any keywords within them. However, they have to maintain their connection to biogas related matters and appear within a same paragraph with the selected keywords. Similarly, not all sentences within a paragraph containing a keyword are relevant to the biogas field or the research question at hand.

The most common statement is formed from one or more sentences, which explain and describe certain aspect in connection with biogas. However, are a few instances, where rules for had to be defined more carefully in order to maintain coherence in the analysis. In certain cases, a single sentence might include multiple statements connected via operators such as “AND”, “OR” and “IN ADDITION TO”. When analyzing paragraphs, where two or more statements are identified within a same sentence, they are segmented into separate sentences, each containing one statement:

> “Energy use of crop biomasses and **biogas** production in connection to larger units of livestock which serves local demand will be developed.”[11]

- ➔ Energy use of crop biomasses will be developed.
- ➔ Biogas production in connection to larger units of livestock which serves local demand will be developed.

[11] “Kehitetään peltobiomassojen energiakäyttöä ja suurehkojen kotieläinyksiköiden yhteydessä paikallista tarvetta palvelevaa **biokaasutuotantoa”**. (MEE, 2001, p. 72; translated by author)

As there are two different statements connected with an operator, this sentence is divided into two statements containing an individual node of information.

It should be noted that not all operators are considered to be an indication of two different statements within a same sentence. The act of differentiation is only done, when contents of a sentence include two nodes of information. However, on every instance where a sentence contains an operator, a sensibility of division is considered.

Table 1. Simplified coding grid. Original paragraph is first translated into English, and then segmented into four different statements. A part of the paragraph is considered to be a repetition and does not appear as its own statement. Only one statement includes the keyword, but in the context of the paragraph the word "bio-based" is considered to integrally include biogas applications. All statements are considered to be explorative as they are suggestive in their general idea or explore future prospects.

Paragraph (Finnish)	**Translation (English)**	**Statements**
Biopohjaisen energian tuotantoa tulisi tarkastella nykyistä laajemmasta näkökulmasta. Huomioon olisi otettava esimerkiksi **biokaasun** pientuotannon myönteiset ympäristö- ja ilmastovaikutukset sekä hajautetun energiantuotannon edistäminen. Pientuotannon edistäminen palvelee maatiloja, joilla on halua edistää uusiutuvan energian käyttöä ja pienentää energiankulutustaan ja nimenomaan ulkopuolisen energian käyttöä. Myönteisellä ohjauksella maatilat voisivatkin kehittyä energiaomavaraisiksi.	Production of bio-based energy should be examined from a larger perspective. For example, positive climate and environmental impacts of small-scale **biogas** production as well as promoting decentralized energy production, should be considered. Promoting small-scale production benefits farms, which are willing to pursue renewable energy production, lower use of energy and especially [to reduce] use of external energy. With positive instruments, farms could develop self-sufficiency in energy.	Production of bio-based energy should be examined from a wider perspective.
		Positive climate and environmental impacts of small-scale **biogas** production should be considered, for example.
		Promoting small-scale production benefits farms, which are willing to pursue renewable energy production, lower use of energy and especially [to reduce] use of external energy.
		With positive instruments, farms could develop self-sufficiency in energy.

Segmentation proves difficult when a paragraph contains a list of elements, where biogas is only mentioned as one example. Following the same logic as with multiple statements with a one sentence, these lists are broken down as in the example below:

> "Fulfilling the obligation requires sharp increase in wood-based energy, waste fuels, heat pumps and **biogas** as well as in wind energy."[12]

> ➔ Fulfilling the obligation requires sharp increase in biogas.

A careful assessment has to be made on whether the intent and meaning of the original sentence remains intact. In a situation where the parts of the original meaning are at risk of being lost, a reminder of the original sentence was included next to the statement in the coding grid.

Statements within a same paragraph, which share the same statement are evaluated based on their thematical connection. If fragments (sentences or words) are scattered in multiple sentences throughout a paragraph, they are considered to be an instance of the same statement. In some instances, where a statement is strongly scattered around a paragraph, a new sentence is formed in order to bring the statement into a more analyzable form.

4.5.3. Evaluating the statements – reduction

Reduction of the statements follows the segmentation, as more careful evaluation of the statements found during the previous phase is conducted. The main goal of this evaluation is to conduct set of clear rules onto which statements are to be included in the analysis. In this study, the set of rules is established by defining the diction of the selected statements first, and then evaluating their informative value in the context of the documents. During the reduction process it is found that the statements fall roughly into two different categories: declaratory statements and explorative statements, wherein rules for inclusion are set more carefully. More practical examples are portrayed in the following subsections.

As this study is interested in the progressive change of perception of biogas field during the selected time period, emphasis is put on statements, which take a forward-looking approach to the biogas field

[12] "Velvoitteen täyttäminen edellyttää niin puuperäisen energian, jätepolttoaineiden, lämpöpumppujen, **biokaasun** kuin tuulienergiankin käytön voimakasta lisäämistä." (MEE, 2008, p. 9; translated by author)

by directly stating what will be changed, or indirectly drawing attention to aspects what ought to be changed. Therefore, the statements, which are included, have to take a forward-looking approach, instead of listing technical or historical aspects of the biogas field. This is not to say that statements pointing out flaws and failures in the contemporary system are not included. If a statement can be considered to draw attention to certain aspects on the biogas field, and to suggest an action to tackle it, it can be considered forward-looking, and is thus included in the analysis.

It should be noted, that the division of statements into declaratory statements and explanatory statements is highly subjective in nature. Moreover, the subjectivity and prior knowledge of the researcher is apparent when evaluating, which statements are to be regarded drawing attention to certain flaws and which merely listing historical developments as a context. Therefore, if the reduction process would be repeated by another researcher (or even by the author after the full analysis was complete), the categorization would likely be highly different.

4.5.3.1. Declaratory statements

Firstly, there are declaratory statements, which mainly portray the historical development or the contemporary status of biogas and connected subjects. Here, most of the statements point out certain technical attributes of current biogas production, such as the number of gas-operated vehicles and the number of biogas plants in operation:

> “**Biogas** contributed 40% of all gas in fuelling in 2014. There were 2 200 vehicles which operated with compressed gas in Finland in the beginning of 2016.”[13]

Moreover, the evaluation finds declaratory statements, where biogas is mentioned in as a part of a larger list of other energy sources:

> ”In Finland, renewable energy sources which are currently in use consist of hydropower, wind power, environmental heat and solar energy, as well as renewable bioenergy, where wood-based fuels, crop biomasses, **biogas** and recycling fuels, are included.”[14]

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[13] ”**Biokaasun** osuus kaikesta tankatusta kaasusta oli vuonna 2015 noin 40 prosenttia. Suomessa oli vuoden 2016 alussa yhteensä noin 2 200 paineistettua kaasua käyttävää ajoneuvoa.” (MEE, 2016, p. 22; translated by author).

[14] ”Suomessa käytössä olevia uusiutuvia energialähteitä ovat vesivoima, tuulivoima, ympäristön lämpö ja aurinkoenergia sekä uusiutuva bioenergia, johon luetaan puuperäiset polttoaineet, peltobiomassat, **biokaasu** ja kierrätyspolttoaineiden biohajoava osa.” (MEE, 2005, p. 17; translated by author).

Finally, there are declaratory statements regarding suggested policy actions. Here the general theme of the statements is more forward-looking, and reflect a mean to a change between the current and the desired state of affairs:

> "Funding for a plausible **bio-SNG** plant is endorsed via the second round of NER300-funding or via other EU funding instruments."[15]

During the evaluation of declaratory statements, it is decided that only statements reflecting directly, or indirectly future use of biogas are to be included in the analysis. This effectively means, that most of the statements, where biogas was originally only mentioned as a part of a longer list of energy sources, or where only details regarding the contemporary context of biogas field were stated, are excluded.

However, in cases where stating of these contemporary attributes were used as a mean to illustrate the large potential of biogas, the statements were included, due to their forward-looking nature. Same logic applies, when biogas was originally mentioned as a member in a larger list and the list itself can be regarded as forward-looking. While listing certain technical aspects of the contemporary status over others does reflect a choice of focus from the writers' part, including these parts seems unjustified in the scope of this study, which focuses largely on the contemporary perception around the theme of biogas. Thus, this paper is more interested in the statements, which are more forward-looking and reflect on a question "what ought to be changed?". This choice of framing proves to be problematic in few instances, where a declaratory statement includes elements from contemporary status and desired development. In these instances, a careful assessment is made on whether whole sentences should be included in the analysis, based on their informative value for the future-looking statements. If the interpretation is prone to change without the notion of the contemporary status, the statement is included into the analysis as it is.

4.5.3.2. Explorative statements

Explorative statements refer to statements, which include portrayals of future possibilities, unexplored pathways and new ways of comprehending and framing the biogas theme. Most of the statements falling into this category refer to new technical advances but also underexplored direct and in-direct benefits from biogas production:

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[15] "Tuetaan mahdollisen **bio-SNG**-laitoksen rahoituksen saamista NER300-rahoituksen toiselta kierrokselta tai muista EU:n rahoituslähteistä." (MEE, 2013; p. 27 translated by author)

> “ [--] **Bio-SNG** can be utilized as vehicle fuel.”[16]

> “**Biogas** production in agriculture can indirectly reduce land conversion into fields, and reduce corresponding emissions to air and water systems.”[17]

Defining this category proves to be difficult as, statements are not categorized by their verb-usage only, but rather to catch the general idea of the whole statement. Therefore, statements such as:

> “Utilizing manure in **biogas** production yields considerable benefits for the environment in addition to acquired energy.”[18]

were categorized to be explorative rather than stative, even when the verb tense alone would suggest otherwise.

Nevertheless, it is obviously not easy to distinguish where a stative statement in a given context imbeds enough explorative status to justify its categorization as an explorative statement rather than as a stative one. Hence, rule-setting and reduction in material and is done prior to further analysis, for it not to interfere or cause confusion with the coding later on.

4.5.4. Coding and creation of subcategories

Coding of the material begins after the reduction process, where the final list of statements is already complete. Here, the goal is to distinguish different ideas and points of focus throughout the selected paragraphs. Statements containing the same theme and intention are situated in the same category. The creation of the categories is done on data-deprived basis, meaning that the categories emerge from the selected material itself, rather than based on an already existing fixed coding grid. Creation of subcategories is inherently connected to the coding process, as statements are situated and resituated into categories throughout the iterative process of coding. Similarly, the division of categories is constantly in change as new categories emerge from the statements. Coding of the material therefore requires multiple iterations, where new categories are created if deemed necessary, after which all the

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[16] ”**[--] [B]io-SNG**:tä voidaan käyttää liikenteen polttoaineena”. (MEE, 2013, p. 27; translated by author)

[17] ”Maataloudessa **biokaasun** tuotanto voi välillisesti vähentää pellon raivausta ja siitä syntyviä päästöjä ilmaan ja vesistöihin.” (MEE, 2016, p. 59; translated by author)

[18] ”Lannan hyödyntämisellä **biokaasun** tuotannossa on siitä saatavan energian lisäksi huomattavia myönteisiä ympäristövaikutuksia.” (MEE, 2008, p. 39; translated by author)

statements are read again in reflection to the new set of categories. Similarly, categories are merged on some instances to better reflect the scope of the ideas embedded in them.

No statement can be situated into more than one subcategory, even if their embedded idea would speak for otherwise. When encountering statements where choosing a category for a statement proves problematic, a possibility for a new category and merging of existing categories are considered. On certain sentences, additional segmentation in a paragraph is deemed as the best alternative, after which suitable categories for the statements be found. This repetition of category building and statement review is continued until no further categories are required and a suitable category can be found for all the statements found during the coding process.

Resulting from the coding process, 18 subcategories are established (table 2). These categories vary in the level of detail as well in the scope of the biogas field. Some categories focus on issues over certain feedstock, while others describe underrecognized co-benefits of biogas production on a more general level. In addition, categories also vary in their emphasis on different themes and perspectives. Technical, economic, and environmental themes are all apparent.

There are several instances, where two or more categories are highly integrated and have an overlap in their themes. This causes some issues when statements are situated in the categories. For example, several statements could be situated in both categories "*Technical advancements*" and "*Piloting*" as these categories both grasp on the future technologies and investments in these new applications. However, some of these sentences appeared in a thematical connection, which could not suit the label of the other category, and two categories were left as separate.

Overall, the coding and categorization process results in highly heterogeneous set of categories. While analyzing categories with varying levels of detail might prove problematic when creating balanced picture of the material, using these categories is considered justified, as the categories emerge from the documents themselves. In other words, if their portrayal of the biogas field does not reflect a balanced view over the issue, the categorization should not either.

In addition to the 18 subcategories, a residue category named *"other"* is created during the coding. This category includes statements for which no suitable category is found despite a number of iterations. Existence of a residue category is often necessary in content analysis. Hence, the coding

Table 2. List of final subcategories. During the coding, 115 statements are found and situated into 18 subcategories. Four statements cannot be found a corresponding category, and are thus situated into a residue category (other).

Subcategory	**Number of statements**
Vast potential for biogas production	17
Transportation	12
Existing gas infrastructure	9
Use of crop feedstock	8
Promotion of waste-based energy production	8
Local and decentralized production	7
Poor profitability of production	7
Manure as a feedstock	6
Need for wider perspective	6
Technical advancements	6
Environmental benefits of biogas	5
Functional business models and value chains	5
Subsidies are required in farms	5
Circular fertilizers and nutrient cycles	4
Administrative procedures	2
Fuelling stations	2
Piloting	2
Other	4
TOTAL	115

process aims for reducing the numbers of statements in this category into a minimum, rather than trying to create categories containing only one statement within them. “Other” category is not included into the further analysis.

4.5.5. Description of the subcategories

VAST POTENTIAL FOR BIOGAS PRODUCTION includes statements, which refer to the underutilized resource base for biogas production. In addition to a vast resource base, this category includes statements, where biogas is given a role to fulfil energy or climate related policy goals, or mentioned as a mean of energy production, which is expected to grow in the future.

TRANSPORTATION includes statements, where biogas is referred in the context of transport sector. These statements discuss and suggest substitution of fossil fuels in road transportation, but maritime usage was also mentioned in a few statements.

EXISTING GAS INFRASTRUCTURE includes statements, where biogas was connected to the characteristics of the gas infrastructure. Most of the statements refer to the existing natural gas transmission grid and how it synergizes with the increased production and use of biogas. Statements in this category are often linked with the use of natural gas.

PROMOTION OF WASTE-BASED PRODUTION has statements, which link biogas and increased use of waste materials. Waste materials in this category refer to industrial and municipal biowaste.

LOCAL AND DECENTRALIZED PRODUTION is a category, which includes all the statements where production and usage of biogas was portrayed in the context of distributed or small-scale units. While there is a difference of definition between small-scale production, local production and distributed production, these terms are at times used in an interchangeable manner in the documents. Therefore, they were situated under the same category.

CROP FEEDSTOCK includes all statements, in which use of crops biomasses is suggested or discussed for biogas production. Statements in this category refer either crop feedstock in general or specifically mention certain types of biomass, such as grass silage or crop residues. Statements mentioning energy crops are also situated in this category.

POOR PROFITABILITY includes statements, where the challenging economic situation in the biogas branch is mentioned. Statements, where a need for further subsidies and other economic instruments are mentioned also fall into this category.

MANURE AS A FEEDSTOCK includes statements, where use of manure is connected to biogas production. Statements in this category discuss the role of manure as a basin for farm-based production as well as the underutilized energy potential embedded in it.

CIRCULAR FERTILIZERS AND NUTRIENT CYCLES includes all statements, which refer to production and use of organic fertilizers, which can be produced as the by-product of biogas production. Additionally, all instances, where soil nutrient balance and closing nutrient cycles are mentioned, are situated into this category.

NEED FOR WIDER PERSPECTIVE includes statements, where the climate and energy centric view on biogas field was either directly or indirectly questioned. This call for wider image can occur as a general statement, or specify a need to include broader value chains or benefits unrelated to energy and climate into consideration. It should be noted that statements including environmental benefits of biogas production are not included in this category, as they also appear separately from statements situated into this category.

ENVIRONMENTAL BENEFITS, in contrast to the previous category, includes statements, which specifically refer to environmental benefits of the biogas production. These statements are often found on a general level, where the different environmental benefits are not specified.

SUBSIDIES IN FARMS includes statements, where the contemporary condition and need for further subsidies in farms are discussed. Statements referring to economic problems in farm-scale production are also situated in this category

FUNCTIONAL BUSINESS MODELS AND VALUE CHAINS includes statements, where biogas was situated in a larger economic context. In contrast to *need for wider perspective* category, the notion of the statements was not insufficient framing in general, but in the way biogas branch operates internally.

TECHNICAL ADVANCEMENTS includes statements, where biogas was discussed in the context of upcoming technologies, and future prospect emerging form these developments.

ADMINISTRATIVE PROCEDURES includes statements, where administrative status in the biogas field is explored. Statements in this category often suggest hastening and streamlining the legal and administrative process before opening a new biogas plant.

FUELLING STATIONS includes statements in which gas-fuelling stations and related operations are mentioned in connection with biogas.

PILOTING includes statements where further piloting for biogas applications is suggested. Both of the statements in this category refer to investment grans, which should be given for new demonstrative projects.

4.5.6. Head categories

Head categories refer to combined categories which are formed from the subcategories. The purpose of head categories is to observe the contents and these of the subcategories and create meaningful connections between them. Head categories allows better examination of the broader messages when it comes to biogas related matters in Finnish energy and climate strategies.

During the analysis, 17 subcategories are situated in five head categories (figure 6). The process of forming head categories is again data-deprived while allowing notions from the existing literature (section 2) and the chosen framework (section 3). However, the formulation process could be described highly intuitive in its approach. Due to the chosen methodology, certain connections emerging from the subcategories have to be chosen over others to answer the selected research question from a selected perspective. This means that some connections that could be formed between subcategories are expected to be lost during the analysis. Overall, the aim of head categories is to include all relevant biogas related information from the documents, within the selected frame of focus. Thus, head categories aim to reorganize and present this information in larger thematical entities to give answer to the research question.

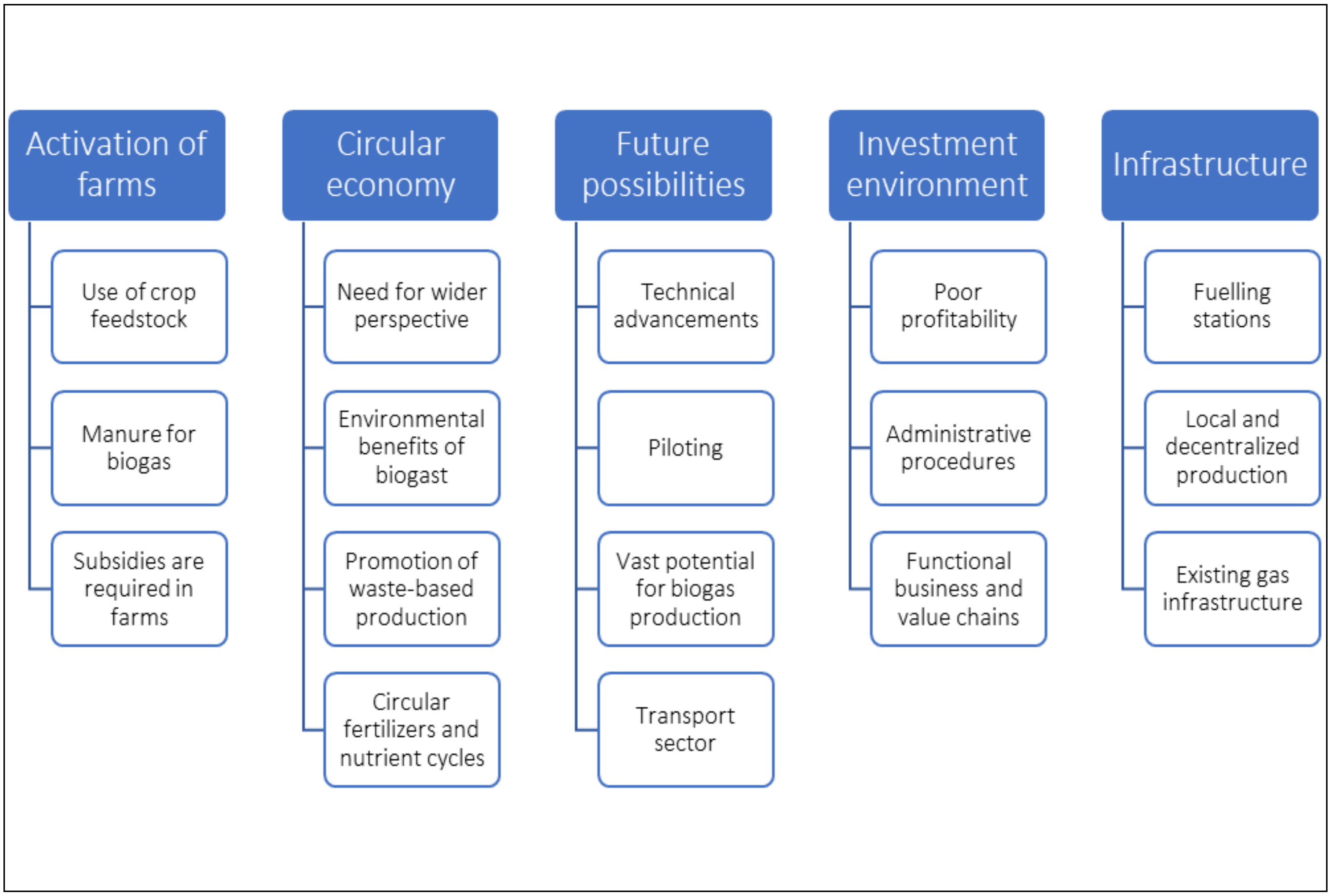

Figure 6. Final composition of the head categories. 17 subcategories containing 111 statements are organized under five head categories. NOTE: category OTHER including four statements is excluded from the analysis before forming the head categories.

5. RESULTS

This chapter summarizes the findings made in the five head categories (figure 6). The categories are described by their contents, and their frequency of measure throughout the documents (figure 7). Additionally, observed internal changes within the categories are assessed. Examples used to describe the head categories are from the original documents.

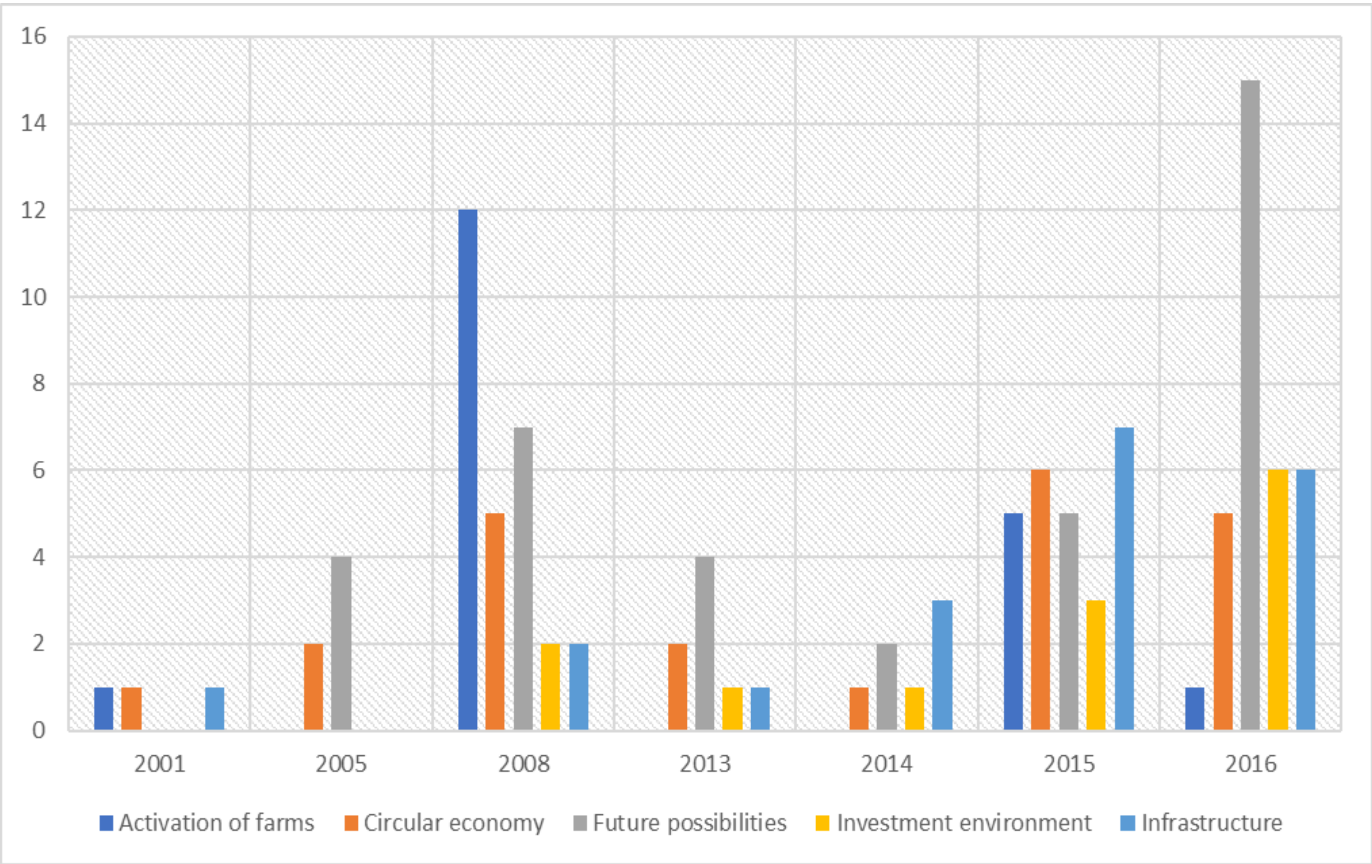

Figure 7. Number of statements sorted by head category and their measure of frequency in the documents.

5.1. Activation of farms

Throughout the documents it is well recognized that majority of the unutilized feedstock for domestic biogas production is bounded to agricultural activities. An emphasis to enable this potential can also be found starting from the first document in 2001. Throughout the documents, manure and crop feedstock are mentioned and promoted as the main resources for agricultural biogas production:

> “Production and usage of energy crops shall be enhanced as well as use of agricultural side streams and manure especially in **biogas** production”[19]

Farms with livestock are portrayed as the basis in unlocking agricultural production, and therefore use of manure as the main feedstock is given attention especially early in the documents. Manure can serve a purposeful feedstock as it is easily collectable from farm shelters and thus does not significantly increase the workload when used in digester. However, two weaknesses for manure-based production are recognized. Firstly, and most importantly, it is highly difficult to make biogas production on-site profitable. While it is recognized that larger concentrated biogas facilities could be an option to ensure sufficient economy of scales, long transport distances limit the profitability of these actions. Secondly, utilizing only manure in production yields a limited amount of biogas when used alone in the digester. Co-feeding other feedstocks such as waste materials, residues or crops is recognized to be beneficial for the methane production. However, poor profitability is mentioned as problem here as well:

> “Co-feeding of grass plants and manure as biogas feedstock has been studied and piloted, but as for now, the poor profitability has hindered the large-scale use of cultivated grass or grass silage in **biogas** production. Profitability may also be limited due to long distances.”[20]

When discussing up-scaling of farm-based production, crop biomasses are mentioned several times throughout the documents. Crop biomasses are understood as any plant mass, which are a direct result of agricultural activities and can be used as a feedstock in biogas production. Key differentiation here is, whether these plants are farmed and harvested particularly for energy production, or rather come as a residue from agricultural activities. Regardless, both are portrayed to contain significant share of the biogas potential. Statements about dedicated energy crops and plant masses is high before 2008, after which the statements refer more to crop residues, side streams and grass. Similarly, crops are mentioned often individually in the earlier documents, but later on manure and crop feedstock are often mentioned and discussed together.

While importance of activating farms in biogas production is apparent throughout the documents, significant hikes in the number of statements happen in 2008 and 2015. While the figure 7 does not

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[19] “Energiakasvien tuotantoa ja käyttöä energiatuotannossa tehostetaan kuten myös maatalouden sivuvirtojen ja lannan käyttöä erityisesti biokaasun tuotannossa.” (MEE, 2008, p. 76; translated by author)

[20] ”Nurmikasvien ja lannan yhteiskäytöstä biokaasun raaka-aineena on tehty useita tutkimuksia ja käyttökokeiluja, mutta toistaiseksi laitosten heikko kannattavuus on estänyt viljellyn nurmen tai säilörehun laajamittaisen käytön biokaasutuksessa. Lisäksi kannattavuus voi olla rajoitettua pitkien etäisyyksien takia.” (MEE, 2015, p. 23; translated by author)

show activation of farms to be a common head category outside of these years, the importance of farms is understood in every document. However, other documents take a rather different stance on how to approach farm-based production, and statements in relation to biogas were often situated in other categories. This is especially true in 2015 and 2016, where farms are portrayed more from the perspective of larger ecosystems.

5.2. Circular economy

Circular economy is the only category, where statements were found in every of the six documents. It should be noted that the term *circular economy* does not appear in the material before year 2016. Yet, it is selected as the name of this category due to it describing the themes within this category.

As can be observed from table 2, almost half of the statements in this category refer to waste-based energy in connection to biogas production. While waste-based biogas solutions were originally approached from the perspective of energy production before 2013, recycling and aspects of improved waste-hierarchy come apparent starting from 2013:

> "By implementing the new waste legislation, prevention of waste generation shall be strengthened, and recycling and use of waste as recollected material shall be enhanced. Additionally, energy utilization of waste, which is unusable for recycling and as reusable material, shall be amplified via increase in waste-burning and biogas production."[21]

Around this time a wider approach was adopted when observing biogas, and aspects of biogas were tied more closely to benefits outside of energy sector. Whereas additional environmental benefits improved manure handling are mentioned already in 2005, this framing is more common later on:

> "Bio-based energy production should be inspected from a wider perspective. For example, positive climate and environmental impacts of small-scale biogas production should be considered."[22]

[21] "Uuden jätelainsäädännön toimeenpanolla tehostetaan jätteen synnyn ehkäisyä, edistetään kierrätystä ja jätteen käyttöä uusiomateriaalina sekä edistetään kierrätykseen ja materiaalihyötykäyttöön soveltumattoman jätteen energiahyödyntämistä jätteenpolttoa ja biokaasun tuotantoa lisäämällä." (MEE, 2013, p. 29; translated by author)

[22] "Biopohjaisen energian tuotantoa tulisi tarkastella nykyistä laajemmasta näkökulmasta. Huomioon olisi otettava esimerkiksi biokaasun pientuotannon myönteiset ympäristö- ja ilmastovaikutukset" (MEE, 2015, p. 27; translated by author)

While the call for wider perspective is more connected to environmental benefits in the earlier documents, economic aspects are included gradually later. While a nominal formal linkage to circular economy is created only in 2016, a gradual change towards this linkage can be observed earlier: Simple linkage between biogas and environmental benefits transforms gradually towards a frame, which includes also aspects of increased economic activity and, at times, security of supply and improved local economy.

Circular fertilizers and nutrient balances are mentioned first time in the material already in 2005, and disappear until emerging again in 2015. Here the same thematical change is noticed, as in 2005 returning nutrients to soil were only mentioned as an additional environmental benefit. However, economic and business aspects of circular fertilizers are perceived as a potential business opportunity:

> "[--] For example, manure and parts of grass biomasses are handled in **biogas** plants, and end products are processed into fertilizers. These [fertilizers] can be either used on-site, or sold outside of the farm. "[23]

Overall, there occurs an observable change of perspective in statements in this category. In the beginning, biogas is perceived from the perspective of energy production and waste-handling. Later, a gradual change towards more comprehensive framework can be found, where aspects of waste-hierarchy and economic activity are especially given attention culminating as circular economy in 2016.

Statements in this category were often found together. This is especially the case in the paragraphs, where calls for wider perspective included environmental benefits and nutrient cycles as examples. However, statements including environmental benefits and nutrient cycles appeared also individually and in other contexts. Another notable observation from this category comes with the scope of the statements. Exactness of the statements varies greatly in this category. For example, some statements were considered about a certain environmental benefit, whereas other mentioned environmental benefits in a general level.

[23] "[--] [E]simerkiksi lanta ja osa nurmikasvimassoista käsitellään biokaasulaitoksissa ja lopputuotteet jalostetaan lannoitevalmisteiksi. Nämä voidaan käyttää joko samalla tilalla tai myydä tilan ulkopuolelle." (MEE, 2015, p. 27; translated by author)

5.3. Future possibilities

Future possibilities is the largest and most difficult category to analyze. It consists of multiple subcategories, which are highly diverse in nature but share one key aspect in common: they approach biogas strongly from the perspective of the future, and aim to either describe or explore potential and role of biogas in the Finnish energy system.

Statements in this category appear in a highly diversified manner. Some statements appear in connection to other categories, most common linkages being vast potential of biogas being linked to agricultural production. On the contrast, statements referring to pilot and demonstrative project appear always independent of immediate connection.

On a general level, the vast potential of biogas is repeated throughout the documents, excluding 2001. Most often a statement refers to a large unutilized resource base, and suggests enabling it to increase biogas production. Biogas is also listed repeatedly as one of the domestic energy sources, which should and could to be promoted in the future:

> "In the strategy, especially sharp increase is presented for use of wood chips from forest residues, crop biomasses, recycle fuels and **biogas**. The goal is to at least triple their share of the used primary energy from about 2% in 2004, to over 6% during the next 15-20 years."[24]

Technical limitations of contemporary biogas applications are noted, but possible possibilities for biogas utilization are added gradually in the documents. The attention seems to shift from traditional heat and power production towards larger systems, where the role of biogas is approached from the system level perspective, like in the case of the transport sector or the overall electricity system:

> "There might also be an opening for entirely new opportunities for **biogas** in marine transport, where international sulphur and nitrogen regulations speed up a transition of vessels to use of liquefied methane."[25]

> "In the longer term, gas markets can be also utilized in electricity system for flexibility purposes (so-called power-to-gas solution)."[26]

[24] "Erityisen voimakkaasti strategiassa lisätään metsätähteestä tehdyn hakkeen, peltobiomassojen, kierrätyspolttoaineiden ja **biokaasun** käyttöä. Tavoitteena on, että näiden osuus primäärienergiasta ainakin kolminkertaistuu vuoden 2004 noin 2 prosentista yli 6 prosenttiin 15 – 20 vuoden aikana." (MEE 2005, p. 20; translated by author)

[25] "**Biokaasulle** saattaa myös avautua aivan uusia käyttömahdollisuuksia meriliikenteessä, jossa kansainväliset rikki- ja typpirajoitukset vauhdittavat alusten siirtymistä nesteytetyn metaanin käyttöön." (MEE, 2016, p. 22; translated by author)

Biogas is presented as an energy carrier with a vast resource base, high flexibility and with multiple potential application in the future. Portrayal of biogas seems to be a niche technology in the verge of commercialization. This perception stays unchanged throughout the documents. The most significant change occurs in the point of focus: While the earlier documents mainly discuss the production side of biogas production and leave most of the end-use unattended, the later documents give also emphasis to the end use of biogas, and approach the biogas question from the perspective of the larger energy system. Especially, high attention given to transport sector is notable in 2015 and 2016. Similarly, the amount of statements referring to synthetic natural gas is high in this category due to its highly experimental nature:

> "Production and use of **bio-SNG** might solve multiple problems in replacing fossil fuels."[27]

While it was expected that the number of statements falling into this category would be high in the first half of the material and slowly decrease, it turned out to be the exact opposite. Majority of the statements are collected from the years 2015 and 2016. While the number of statements in earlier documents hiked in 2008, they were on a decline until 2015. This hike in later documents is observed to be due to subcategory *transport sector* in which the number of statements spikes heavily during the last two years.

5.4. Investment environment

Statements in this category approach biogas from the point of business activities and refer to economic conditions of biogas system. Poor profitability of biogas production, need for further subsidies, and requirement for further policy instruments are recognized starting from 2008, from which the economic situation remains largely unchanged. Statements referring to poor economic condition of biogas plants state the problem, but highlight the large payoff, if the profitability issues will be solved in the future:

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[26] "Pidemmällä aikavälillä kaasumarkkinoita voidaan hyödyntää myös sähköjärjestelmän joustona (niin sanottu power-to-gas -ratkaisu)." (MEE, 2016, p. 41; translated by author)

[27] **Bio-SNG:n** tuotanto ja käyttö voisi kuitenkin ratkaista useita fossiilisten polttoaineiden käytön korvaamiseen liittyviä ongelmia. (MEE, 2013, p. 27; translated by author)

> "In the future, it would be possible to treat significant portion of manure from farms and concentrations of farms in **biogas** plants, provided that the feasibility of the production can be improved by, for example, gate fees."[28]

Statements referring to functional value chains in biogas system appear from 2014 onwards. Value chains outside of sole energy production are recognized and emphasis is put on their functionality as the key component to increase profitability of the overall biogas production. Emphasis is also put more on increasing the business side rather than increasing the energy production in particular:

> "Resource effective, profitable, and environmentally beneficial value chain should be created, when utilizing agricultural biomasses and waste in energy production."[29]

> "[--] Expansive Finnish business activity shall emerge around **biogas**."[30]

To support of this new emphasis in business, administrative procedures are reconsidered and clarified in order to support and speed up the emergence of the more profitable value chains. This includes both national regulations and procedures and relevant legislation in the EU-level:

> "Investments in **biogas** can be supported by enhancing national regulations and streamlining permission procedures. One measure is to affect in EU-level and the guidelines for governmental support."[31]

Overall, biogas is treated as a business in this category more than anything else. During the timeframe, the focus shifts sharply from sole energy production into system of multiple interlinked value chains, which need to function properly in order to make biogas business attracting as a whole.

This category shares similarities with the later notions in *circular economy* category, especially in its the emphasis in situating biogas as part of larger system. Strong linkage between value chains, business

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[28] "Tulevaisuudessa suurten tilojen ja tilakeskittymien lannasta merkittävä osa olisi mahdollista käsitellä **biokaasulaitoksissa**, jos toiminnan kannattavuutta pystytään parantamaan esimerkiksi porttimaksuilla" (MEE, 2015, p. 26; translated by author).

[29] "Maatalousbiomassaa ja jätteitä energiantuotannossa hyödynnettäessä tulee pyrkiä kehittämään resurssitehokkaita, kannattavia ja ympäristöhyötyjä tuottavia arvoketjuja." (MEE, 2015, p. 4; translated by author)

[30] "[--] **[B]iokaasun** ympärille kehittyy kasvavaa suomalaista liiketoimintaa" (MEE, 2016, p. 21; translated by author)

[31] "Kehittämällä kansallisia säännöksiä ja sujuvoittamalla lupamenettelyjä voidaan edesauttaa biokaasuinvestointien syntymistä. Yksi keino on vaikuttaminen EU-tason toimiin sekä valtiontukisuuntaviivoihin." (MEE, 2016, p. 22; translated by author)

models and different aspects of circular economy are found throughout the documents. Number of these statements increases gradually towards the end of the timeframe in material.

5.5. Infrastructure

In the final head category, biogas is approached from the perspective of the infrastucture. Linkage between biogas and the existing gas infrastructure are discussed in addition to possible expansions to the gas delivery system. This category also links biogas into security of supply via synergies with natural gas through the shared gas infrastructure and applications, and via notions of distributed production.

Biogas suits the needs of distibuted production well due to its high locality on both production and utilization. Therefore biogas is perceived as a key component of distibuted energy production thoughout the documents. Major incentives for increase in distributed production are seen in increased economic activity in local level and in stenghtened security of supply:

> "Promotion decentralized, local and renewable energy production increases local and regional security of supply."[32]

A strong linkage to cost-effectiveness and security of supply is also created between natural, biogas and synthetic natural gas. Multiple statements mention the shared features of these gasous fuels and mention the role of the existing gas infrastructure and end-use applications, such as gas vehicles. Natural gas is portrayed as a bridge-fuel, and usage of natural gas is beneficial for biogas:

> "Use of natural gas is supported by [--] preservation of infrastructure for **biogas** and bio-based **synthetic natural gas** in transportation and usage purposes."[33]

As all of the natural gas in Finland is imported, biogas and synthetic natural gas are portrayed to supplement natural gas supply during sortages and allow building of distibution outposts in areas which are out of the reach of gas distribution pipeline:

[32] "Edistämällä hajautettua, paikallisiin ja uusiutuviin energialähteisiin perustuvaa energiantuotantoa lisätään paikallista ja alueellista energian huoltovarmuutta." (MEE, 2015, p. 5; translated by author)

[33] "Maakaasun käyttöä puoltaa [--] infrastruktuurin säilyttäminen **biokaasun** ja biopohjaisen **synteettisen maakaasun** siirrolle ja käytölle." (MEE, 2014; p. 70-71; translated by author)

> “Distribution network for biogas can be supported by light disribution stations, which could be founded for example in connection to farms or biogas plants, or along the main roads.”[34]

It is notable, that only in 2016 biogas gains the primacy over natural gas when discussing the relation between the two. Before that all statements seem to hint that the emphasis is given mostly to natural gas.

Similarily to other categories, this category undergoes a transformation, where more components and dimensions to the original statement are added gradually. Statements about infrastructure in the early documents are mainly interested in increasing distributed production, whereas clear connection to security of supply, local employment and co-usage of biogas and natural gas are added later on. This might be due to decarbonization effors in transport sector, which gained a lot of attention in the material during 2016. Most of the statements in this category are found in the documents dating to 2015 and 2016 (figure 7).

[34] “**Biokaasun** jakeluverkkoa voidaan myös täydentää kevyillä jakeluasemilla, joita voidaan perustaa esimerkiksi maatilojen tai biokaasulaitosten yhteyteen tai valtaväylien varrelle.” (MEE, 2016, p. 22; translated by author)

6. DISCUSSION

6.1. Reflections on the framework

The way Finnish energy and climate documents have addressed biogas has undergone major adjustments. At first, biogas was seen majorly as a renewable energy source with benefits in climate change mitigation and local environmental benefits. Later on, more comprehensive understanding of biogas field has been formed, where biogas is linked more with notions of larger economic constructs. On a higher political level, biogas has been progressively been coupled with more diverse notions of circular economy and on a lower level, importance of functioning and encouraging business environment is better understood. Similarly, statements mentioning enhanced security of supply and local economy have gained more attention over the time.

Despite the observed changes occurring within the categories, the set of categories remains largely the same, meaning that the same themes are discussed continuously. Most notably, there seems to be a major trust put in the technological advancements, which might provide new technological solutions in the biogas field, and possibly enhance the profitability by providing new applications for biogas in the future. At the same time, poor profitability of production is repeatedly discussed, but based on the documents, this issue was never resolved, as the discourse remains largely unchanged.

While more linkages between biogas have been made cross the traditional energy and climate policy domains, it seems to have had little impact in the reality. The use of biogas has remained rather low in Finland since 2005 (M. Huttunen et al., 2018), despite the efforts to address biogas as part of a larger strategy and adding the list of benefits resulting from biogas production. Time between 2001 and 2016 saw the annual biogas production double from around 350 GWh to 700 GWh (M. Huttunen et al., 2018), yet this might not be considered as a major success. During the same timeframe, annual electricity production from wind power grew from less than 100 GWh to over 3000 GWh, a thirtyfold increase (Finnish Wind power Association, 2016).

According to the framework of this study, three components affect the state's perception of the energy policy domain: perception of the landscape pressure, perceived strength of the regime and perceived costs related to niche alternatives. These perceptions are manifested in the comparison between the existing regime and possible niche alternatives in light of the landscape developments. This state-centric approach gives some tools to explain the results.

On the domestic level, state might perceive biogas niche too weak and expensive when compared to other niche alternatives and solutions produced within the dominant regime. Finnish policy making in energy affairs has been focused on traditional energy sector, and Finland's historical orientation towards bioenergy is highly apparent to this day (Toivanen et al., 2019). Wooden biomasses are already central in the Finnish energy system, thus achieving central attention in energy related policy making. This notion is supported by the hike in statements around wood-based bio-SNG in year 2013, when it gained more attention than traditional biogas from anaerobic digestion. This historical path dependency might cause unexpected problems for biogas, even though biogas niche should be greatly benefitting from the frameworks favourable for bioenergy. Biogas niche seems to not gain enough attention from the regime level, where other alternatives, such as wooden biomasses, are preferred. Simultaneously, biogas is not considered as a new renewable energy niche in a same sense as wind and solar power, which are emerging from outside of the regime. In other words, competing niche innovations are able to increase their attractiveness in the protective space on the niche level, while solutions more closely tied to regime gain benefit of the regime-centric perception. This might have left biogas niche in a difficult position, where state's perception of the biogas niche is majorly influenced by both niche and regime level solutions. Combined with poor profitability and the novel nature of the biogas niche, biogas might be considered as an inferior and costly solution, which steers the state and other actors to look for other alternatives.

On the landscape level, perceived pressure seems to be inadequate for the state to justify engaging in costly reorientation. As noted above, when biogas question is approached from the perspective of energy production and climate change mitigation, other alternatives are seen preferable when reacting to the pressure. Change in the state perception could happen, if biogas field was approached from a different perspective, which would force the state to address the cost of reorientation in a new light. For example, in many European countries, natural gas has a highly political dimension (Smith Stegen, 2011) and this has created a strong incentive to enhance the national gas production (Scarlat et al., 2018). Considering that natural gas contributes around 25 TWh to the Finnish energy mix, and gas consumed in Finland is imported from Russia (Energy authority, 2019), reducing reliance form the imports seems to create a strong state incentive to find alternatives. Therefore, it is striking that change of approach in biogas versus natural gas question seems occur only in 2016. Before, the synergies between shared gas infrastructure were noted, but role of biogas was perceived to be supplementary instead of substitutive.

This change in perception may serve biogas niche in a positive manner, as energy security agenda is often deemed one of vital importance by states (Cesnakas, 2010). Due to the flexible nature of biogas as an energy carrier, its role in substituting natural gas is less contested compared to substituting fossil fuels generally in energy production. Gaseous solutions are central during the increase of intermittent electricity production, as gas turbines are currently the most feasible choice for grid balancing purposes. Moreover, increase in the use of gaseous fuels could enable use of new low-carbon technologies, such as power-to-gas solutions. These benefits and limitation of technological alternatives could be supportive for the biogas niche, provided that the pressure from landscape is perceived to be strong enough. Adding energy security and security of supply to this perception could show biogas in more attractive and cost-effective light, compared to biogas being addressed as a mere tool for GHG reductions.

Similarly, if biogas was approached primarily from the perspective of local economy and environmental benefits as was arguably done in Sweden (Olsson & Fallde, 2015), more local and practical approach to biogas production could be adopted. The state might not need to adopt a proactive stance on biogas question, but a rather reactive one, where legislative and regulatory barriers for production are solved gradually in cooperation with local level actors. This cooperation, where the agency is given mainly to local actors, instead approaching the field from national level, would enhance communication not only between local and national level actors, but also on the local level thus enhancing the development of biogas systems organically in a bottom-up fashion (Suonio, 2016). This could have positive impact in the state’s perception of the biogas field, by potentially reducing cost of reorientation in state’s perspective. This would allow state to act as an enabler, instead of a planner who proactively tries to set goals and targets for the biogas field. While active goal setting creates stability and predictability on the biogas sector, it may also act against its purpose, if investors and other actors in the field are continuously discouraged by falling short of the targets set on the state level. Similar affect may happen in state’s perception of the biogas field, resulting biogas to be treated as a lost cause.

As Winquist et al. (2019) notes, Finland is yet to recognize the full potential of domestic biogas. The landscape pressure is perceived to originate from developments in climate change and energy domains mostly, making reorientation in the regime somewhat desirable, yet state seems to be unwilling to engage strongly with it. The pressure seems to be inadequate for the state to push for stronger means to promote biogas in practical sense, which could manifest as the poor attention given to the biogas field in practice, observed by S. Huttunen et al. (2014). Historically, biogas has been perceived to be a domestic energy resource, with a great potential to reduce GHG, accompanied with additional benefits outside of the energy and climate change domains. However, the connection of these benefits under larger umbrella seems to be done gradually, culminating in stronger connection with circular economy and strengthening versatility of biogas only during the last years of assessment. This seems to have left other benefits from biogas production more ambiguous, resulting in a flawed perception of the cost of reorientation. If connection between circular economy, security of supply, local economy and environmental benefits could be strengthened further, perceived cost from integrating biogas into the current regime might be deemed lower than it has been. This, together with constantly increasing pressure from climate change and energy security agenda, could encourage state to engage more actively with biogas field, and support the according adjustments in the energy regime.

6.2. Reflections on biogas literature

6.2.1. Transport sector

While the general themes within categories have remained largely same, increased focus for transport sector can be observed from 2015 onwards. In the documents dating 2015 and 2016, there is a heavy emphasis on increased use of biomethane in vehicles as a domestic and climate-friendly solution for the transport sector, where decarbonization is notoriously hard (S. Huttunen et al., 2014; Pääkkönen et al., 2019). Transport is perceived as an emerging niche technology, which could solve multiple contemporary problems with biogas usage, when it comes to profitability of production, constraints on transport distances, thus ensuring stable demand by providing biogas a technically and economically feasible substitutive role in transport sector.

High emphasis given to transport sector during the last two documents indicates a markable change in the perception over biogas field. Before this, policy documents seem to have considered biogas on a general level, emphasizing especially the resources and production. With the introduction of transport-centric vision over biogas field, the end-use sector emerges to highlight the need for balance between supply and demand, which is required for any energy resource. While it is indefinite to say how this change in paradigm might affect policy making in the long run, it definitely has made the complexity of the sector more apparent. It is certain that focusing on a certain pathway paints a more clearer picture for biogas, enhances stability in the sector, and thus encourages willing actors in the sector to act accordingly (Winquist et al., 2019). However, where introducing gas-operated vehicles in the transport might sound a reasonable solution in the paper, promoting one certain pathway for biogas might steer production into inefficient direction in the terms of climate change mitigation and economic prospects. As noted above, biogas system is often most effective, when the planning is done on a local level (Eker & van Daalen, 2015). Promoting certain pathways over others on a national level might give a wrong impression, where it threatens to negate these local level realities in production and end use, unless attended in a more practical level of policy planning.

One might wonder, why transport sector is categorized as a potential technology in this study, despite there already being commercially viable applications of biomethane production and gas operated vehicles. While it is true that use of vehicle gas has been ramping up during the latter half of 2010s, this change might not portray the vision provided in the documents. As it is in 2020, biogas has still remained a rather niche solution in transport sector, where biofuels and electrification are gaining momentum over it. Moreover, major share of the produced biogas still remains utilized in heat and power production, while use and production of renewable vehicle fuel is lacking significantly behind (M. Huttunen et al., 2018). Compared to more traditional means to utilize biogas, heat and power production, production of vehicle gas is technically more demanding and requires careful attention over the whole value chain, including sufficient delivery infrastructure and demand for the biomethane produced. Gradual steps towards this more holistic approach have been made throughout the 2001-2016, and the effects of these changes in perspective might yet to be in full effect.

While giving emphasis to building a clearer, more predictable and better structured investment environment is something that investors often hold dear (Hasan & Ammenberg, 2019), it might be not enough to push biogas into the regime without help of the state and new policy instruments. Finland has been reluctant to introduce new subsidies on the transport sector, and arguably for a good reason. Introducing new subsidies in the sector is hard, as subsidies in the demand-end, such as vehicles, might end up promoting imported natural gas instead (Pääkkönen et al., 2019). Something, that may not be seen as a feasible solution by the state or other regime actors. Regardless, it is certain that introducing large amounts of biomethane in the transport sector would require major changes in multiple trajectories of the current regime, and hard political dedication to push these changes forward.

6.2.2. Agriculture and local level emphasis

The role of agriculture in biogas field is arguably the most diverse one. Farms could simultaneously act as producers of resources, producers of energy, and end-users of the biogas, as well as a key actor when considering use of the nutrient rich by-product, resulting from biogas production. Majority of the methane potential result from agricultural activities, and this gives actors in agriculture a central role in any biogas system, which wishes to utilize the still largely underutilized resource potential in energy production. Throughout the beginning of 2000's, policy documents in Finland have recognized the role of agriculture in biogas systems, and given it somewhat good attention. However, this attention is often given in a fragmented matter, where the role of agriculture is given is either a resource producer, or an end-user. This seems to promote the idea, where biogas should be both produced and utilized in farms, which would require smallest amount of movement of feedstock or produced energy.

Questions arise from the strong emphasis in encouraging use of agricultural resources in biogas production. Plants such as grass have been recognized to have strong potential in biogas production, but so far, their usage has remained limited despite the strong role given in the policy documents. Usually this lacking development is credited to poor profitability of production and lack of necessary business models, which could encourage actors to seek biogas production from crops. However, not much attention given to the influence of policy frameworks and regulations, which affect usage of crops in energy production directly or in-directly.

While introduction of a new legislative frameworks, such as REDII directive (European Union, 2018) in 2018, is unlikely to affect the economic feasibility of crop-based biogas production in the short term alone, it still creates additional level of regulation and more administration on a sector, which is already described difficult to comprehend by many actors (Winquist et al., 2019). In the long run, increased complexity over what is considered renewable and sustainable bioenergy production is likely to affect entry criterion of national subsidy schemes. This will certainly affect the perception of the state as well as interest of possible investors, by creating ambiguity over the feasibility of biogas production when it comes to utilizing crops. If crops were already hard to enable in biogas production, it is unlikely that gradually increasing regulation makes it any easier. This is especially true, when new frameworks are to govern usage of biomass or energy in general, as it easily negates the current state and characteristic of niche innovation, such as biogas in this case. Unless additional efforts are made to provide significantly more clarified framework in the biogas field in terms of regulation, it is hard to see the increasing legislation to be benefitting biogas production.

As recent studies have shown, farm-scale biogas production is hard to optimize economically. Even with careful planning, it is hard to make biogas production profitable under a subsidy system, where an investment grant requires biogas to be mainly utilized on site (Winquist et al., 2015). Without an investment grant, the profitability of a system is even harder to achieve, despite the added income from biogas sold in farm-scale production. While introducing transport-centric view on the biogas system provides tempting opportunities for farms, it acts against the idea, where biogas should be produced and utilized in the same area. With added costs from biomethane production, the risk of investment grows rapidly, and may alienate potential farmers from the business. Farm-based production could enable the agricultural resources for biogas production and provide the basin for expanded gas fueling infrastructure for increased number of gas operated vehicles (Mutikainen et al., 2016). However, it would require a strong effort and mutual understanding from local level actors to support the biogas operation via larger integration, for the system to grow and operate in an optimal manner (Suonio, 2016).

In the latter documents, where functioning business models and expanded value chains may improve the profitability of the overall biogas system, farms and farmers are also placed as central entrepreneurs within the larger value chains. While this recognition should be welcomed, as it highlights the importance of creating deeper integration between actors of biogas value chain (Aro et al., 2018), the transition from mere resource producer and/or end user to an central actor within larger ecosystem might create problems within the practical level. In Norway, this larger level of integration was seen to produce contradicting results in the terms of climate change mitigation. While evaluating, how different levels of integration effected the economics of biogas production, the economic profitability was at its lowest in system, where accumulated reduction of GHG was at its highest (K.-A. Lyng, 2018). Moreover, the study found that substantial subsidies are most likely required, if agriculture was to be integrated as part of the larger biogas system. Similar problem may be found in Finland, where subsidies for agricultural biogas production have been even lower than in the neighboring countries. This would imply that if biogas production including agricultural resources is evaluated only in the terms of energy produced and emissions avoided, biogas may often seem an expensive and ineffective choice. Overall, the total impact of the biogas systems should be evaluated, and farms should be better recognized as a central actor, when it comes to upscaling this potential. As important is, to give proper attention to practical realities in farms when it comes to policy planning and economic incentives. Integration of agriculture into biogas systems is unlikely to happen, as longs as the exclusive energy and climate centric approach in decision making is maintained, as it makes costs of agricultural biogas production seem too great compared to the pressure from landscape developments and other competing alternatives in the Finnish energy system.

7. CONCLUSION

In this thesis, development of the Finnish biogas field was studied throughout the 2000s. Content analysis was used to categorize seven key policy documents to describe the trends in the state's perception of the biogas as a niche innovation.

Theoretical synthesis was made to introduce state's behaviour into the multi-level perspective. States are unique regime actors, which occupy a central role between landscape level and regime level. State's interpretation of the landscape-regime interaction is vital, as state possesses the authority to reshape energy system into desired direction as well as support niches it finds suitable in this process. This suggests that state constantly evaluates all three levels of system, landscape, regime, and niche innovations, trying to find an optimal formulation for the national energy regime, in order to match up developments from the landscape in a national level. However, state's perception of the levels is influenced strongly by regime-centric perspective. Path dependencies, system lock-ins and historical way of doing may twist policy formulation done by the state, resulting in suboptimal preservation of status quo. Further research has to be undertaken to better understand the internal process of perception building, when state evaluates landscape-regime or regime-niche interactions. Moreover, better conceptualization is required for the cost of consequence, which is here understood only as a sum of perceived effects related to regime reorientation.

Finnish policy documents were found to have undergone changes during the years, but the overall topics have remained same. Biogas was perceived as an energy source with a lot of domestic potential but enabling it had proved difficult. Agriculture was highlighted as a central actor in the matter, but their role was described in an ambiguous manner. Farmers were treated either as producers of feedstock, producers of energy or consumers of energy depending on the year and context. Notions of material circulation grew gradually, and connection to circular economy was made in 2016. Biogas was earlier seen only as a mean to produce energy, but later it was emphasized more as a business, which required functioning business models and encouraging business environment to grow. Infrastructure and synergies with natural gas were highlighted during later years, giving more notion to security of supply and distributed production. Positive synergies with the existing natural gas infrastructure were recognized, yet expanding the delivery and fuelling systems was perceived as a precondition to increased biogas usage, mostly in relation to biogas usage in transport sector.

Against this framework it would seems that by evaluating biogas only through the lenses of energy and climate policy, state regards biogas as an expensive and ineffective solution. Other alternatives, such increased use of wooden biomasses hold a strong foothold in Finland already. Similarly, other new renewables, such as wind power, have benefitted from their clear position in the energy field, making them seem more feasible solutions. Biogas, instead, yields multiple benefits outside of energy sector, such as strengthening of local economies, enhancing security of supply and advancing material circulation. Enhancing the connection between the different benefits from biogas usage could be a way to influence the state's perception of the system costs related to biogas niche. However, this would require a change of perspective from state's part, which currently approaches energy and climate domain in a highly exclusive manner.

In more practical terms, transport and agricultural sector focus were discussed. In 2016, a strong emphasis towards transport centric approach was adopted. This marks a visible change to the historical view on biogas sector, as certain sector in the end use was strongly connected to biogas production for the first time. While this change might create stability and predictability over the biogas field, giving it more identity, strong subsidies and political will are more likely needed to generate inertia in the sector. In the agricultural sector, local rationales of biogas production have gone mainly unnoticed. Enabling parts of the vast energy potential nested in manure and crop residues might be possible, if state adopted a role on an enabler, instead of a planner on the matter. Biogas ecosystems could form organically, if state strongly supported the growth of these local systems, and solved biogas-related problems gradually with local actors as they emerge.

A transformation takes its time, so it may still be too early to judge the definite effects of policy actions resulted from the latest climate strategy, which took a more focused approach to transport sector specifically. Same applies for the state perception, which is likely to change, if the connection between biogas related benefits are redrawn and strengthened further. During the time of writing this thesis, planning of the national biogas plan has started with the first official comprehensive report on the matter released in 2020, where many of these issues have been gained more attention. (Ministry of Economic Affairs and Employment, Ministry of Agriculture and Forestry, Ministry of Transport and Communications, Ministry of the Environment, & Ministry of Finance, 2020). This definitely helps to highlight the entirety of the biogas sector and renders many of the cross-sectoral issues in policy planning into a more transparent form. However, the practical impacts of the new comprehensive framework and actions proposed in the report remain to be seen – provided they are applied.

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