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AGRICULTURAL GREEN GAS DEMONSTRATION PROJECTS IN THE NETHERLANDS. A STAKEHOLDER ANALYSIS

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Abstract

In the Netherlands green gas is seen as a sustainable alternative to natural gas. However, green gas is still not competitive to natural gas in terms of pricing, and production volumes are remarkably low. Currently, there is a lot of attention to green gas which stems from upgraded biogas, which is produced by manure-based anaerobic co-digestion by livestock farmers. In this article the central question is to understand green gas demonstration projects from stakeholders' perspectives, and identify barriers accordingly. The results of our analysis show that a disproportionate burden lies with biogas producers, who are therefore unwilling to invest. In large part this is due to juridical-administrative stipulations that provide gas grid operators with little incentives to invest, notably in biogas infrastructure and biogas treatment equipment. However, biogas producers face many more risks and challenges: (production) subsidies not being granted, legal permits to operate biogas plants not being granted, limitative environmental policies that restrict business operations, and price instability regarding co-feedstock. Moreover, access to bank to loans has declined strongly in recent years. Altogether, the risks potential biogas producers face, the lack of regulatory incentives grid operators have to engage in green gas business development, and the lack of market demand among end-consumers, do not favor green gas niche development. This can only change when policy makers design stakeholder specific strategies to solve those barriers; e.g. public investments funds to cover for high upfront costs, and regulatory changes regarding the role and competences of grid operators.

Key words: biogas, biomethane, energy transition, implementation, renewable energy, stakeholder analysis

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1. Introduction

Economies are bound to change. The finiteness of natural resources, overexploitation of soils, dependency on fossil fuels, and climate change demand a rapid, innovative, and sustainable approach to foster the interests of current and future generations. Renewable energy sources play a central role in providing energy services in a sustainable manner and, in particular, in mitigating climate change (IPCC, 2011). On a global basis it is estimated that renewable energy accounts for 12.9% of the total 492 EJ of primary energy supply in 2008 (IEA, 2010). The largest contributor is biomass (10.2%). Under most conditions, increasing the share of renewable energy in the energy mix will require policies to stimulate changes in the energy system. Government policy, the declining costs of many renewable energy technologies, changes in prices of fossil fuels and other factors have supported the continuing increase in the use of renewable energy. While renewable energy is still relatively small, its growth has accelerated in recent years (IPCC, 2011). In Europe, biomass conversion is considered a renewable, environmentally-sound way to produce energy. The EU strives to achieve a 20% share in the

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total energy mix by 2020. Next to lowering greenhouse gas emissions renewable energy is also perceived as a way to use natural resources in a more sustainable way (Fischer et al., 2012).

Although there is much discussion in the Netherlands about energy transitions, implementation of renewable energy is low compared to other European countries (Verbong and Geels, 2007). In the Netherlands, biomass is the main source for renewable energy generation (over three-quarters of renewable energy sources; Raven, 2005). The Netherlands aspires to achieve a 14% share of energy derived from renewable energy sources by 2020. To do this, the Dutch central government has put great emphasis on bio-energy, especially anaerobic co-digestion, which it considers to be a mature conversion technology (Agentschap NL, 2011a). The anaerobic co-digestion energy output – biogas, a mixture of methane (50 to 70%) and CO_2 - can be utilized for different purposes, including upgrading to a higher methane content (89%), which can be injected into the natural gas grid and can also be used directly in vehicles (Petersson and Wellinger, 2009). In the Netherlands this is also known as ‘green gas’.

Biogas production from manure anaerobic co-digestion (from now on to be referred to as: co-digestion) has received a great deal of attention in academic literature (Geels and Raven, 2006, 2007; Markard et al., 2009; Negro et al., 2007; Negro and Hekkert, 2008; Raven, 2004, 2005, 2007; Raven and Geels, 2010; Raven and Gregersen, 2010; Verbong et al., 2001). Although agricultural biogas production capacity has increased tenfold during the 2000-2012 period (Rabobank Food & Agri, 2013), “niche development in the Netherlands has shown clear ups and downs, in a non-linear pattern” (Geels and Raven, 2006), and is generally considered to have had little success (Geels and Raven, 2006; Hofman, 2005; Negro et al., 2007; Negro and Hekkert, 2008; Raven, 2004, 2005). Geels and Raven (2006) explain non-linear development through the interaction of learning processes, network building and articulation of expectations. Niche development of biogas production from co-digestion is considered more successful in other countries, in particular Germany, Denmark and Austria (Geels and Raven, 2007; Markard et al., 2009; Negro and Hekkert, 2008).

Although developments for biogas production from co-digestion in The Netherlands have been not been successful thus far, there are great expectations in relation to utilization of ‘green gas’. It has even found favor with the major players in the energy industry, especially central government, the energy companies and regional gas grid operators, because it can be utilized as a substitute for natural gas and fed into the natural gas grid, which is the key energy infrastructure in the Netherlands. Green gas is therefore not restricted to local use only. In theory it can be used throughout the country at any given time. Alternatively, it can be used as fuel for sustainable mobility, either as green gas for gas-fired vehicles, or as Bio-LNG for special, large industrial vehicles.

Because more than half of the energy used in The Netherlands comes from natural gas, substitution with ‘green gas’ offers great future potential for greening the domestic energy market. Expectations are that green gas will become an effective means to increase the share of renewable energy in the domestic energy mix (Gasterra, 2008; Stichting Groen Gas Nederland, 2011). Moreover, green gas is viewed as the key energy carrier in the transition towards a ‘green’ energy economy by 2050, when the Netherlands aspires to lower its CO_2 emissions by 90% below the 1990 level. Based on the potential of biomass available for biogas production, especially a surplus of animal manure, the expectation is that green gas could produce up to 30 PJ per annum in the Netherlands. Gas grid operators expect that up to half of the Dutch gas mixture will be ‘green gas’ by 2050. This goal has been set as a ‘speculative target’ by a Green Gas taskforce in 2007 (Platform Nieuw Gas, 2007), and was later adopted by the Dutch energy grid operators association ‘Netbeheer Nederland’, assuming that next to co-digestion, biomass gasification would account for a substantial growth in green gas production (Netbeheer Nederland, 2011). The short term goal set in 2007 was initially attaining 8-12% green gas in the total gas mix by 2020 (Platform Nieuw Gas, 2007), but was later adjusted (in 2012) to 4% (ECN, 2012). Achieving this target fits in with the Ministry of Economic Affairs’ broader goals of realizing a European ‘Gas Roundabout’, within the Netherlands, thanks to its gas reserves and geographical location, acting as a central node in the international natural gas market (as a ‘hub’ between the Anglo-Saxon countries, continental Europe and the Nordic countries). Furthermore, gas suppliers and gas grid operators advocate green gas as an argument to extend the productive lifetime of the well-developed natural gas infrastructure of the Netherlands. The strong arguments offered by these key stakeholders in the energy sector have helped convince the Dutch central government to allocate €1 Billion (SDE+ subsidy scheme) in support of green gas demonstration projects in 2011; out of a total of €1.5 Billion for multiple renewable energy technology routes (Min. EL&I, 2011a).

All these expectations assume that after initial government support (i.e. the SDE+ subsidy scheme), large-scale green gas production will become competitive and go into commercial operation - that is, without future government support. Currently, however, this expectation is very far indeed from being met (Sanders and Hoppe, 2013). Although green gas is considered technologically advanced, or even ‘mature’ (Agentschap, 2011a), it is still not competitive with natural gas. Although green gas supply volumes are increasing, the supply - 22 Million Nm^3 per annum (for 2011) – represents only a small fraction of the overall domestic gas market. Together with (other forms of) biogas, it replaces 300 Million Nm^3 natural gas per annum, which is approximately 0.6% of total domestic gas use (ECN, 2012). These numbers illustrate the infant state of green gas development in the Netherlands. There are a number of reasons why market development is currently rather poor. More generally, green gas production and utilization require economies of scale (for green gas produced from landfill gas this is hardly a problem, but for green gas produced from farm-scaled co-digestion it is). For that reason, multiple stakeholders in the green gas production chain have to cooperate, notably biogas producers, regional gas grid operators, energy companies, potential end-users, and local governments.

In this paper we focus on green gas from upgraded biogas, which is produced in farm-scale co-digestion plants. Demonstration projects of this bio-energy conversion method are currently in preparation. It is in these regional demonstration projects that efforts are made to achieve economies of scale by developing a green gas value chain. Here we focus in particular on the 'BioNOF' case (abbreviation for the Biogas Grid 'Noordoost Fryslân'). In this demonstration project, which is still under development, a 32 km biogas pipeline is planned to connect distributed biogas production (from twelve or more biogas producers) to a central location, where the biogas will be upgraded to green gas and then injected into the natural gas grid. The ambition is to produce biogas at the rate of 10,000 Nm^3 per hour (E-Kwadraat, 2011). In this project the biogas producers are dairy farmers, who use the manure surplus from their cows as the main feedstock (besides co-products for substrate) for co-digestion.

This case study is academically positioned in the debate surrounding biogas niche development (Geels and Raven, 2006, 2007; Markard et al., 2009; Negro et al., 2007; Negro and Hekkert, 2008 Raven, 2004, 2005, 2007; Raven and Geels, 2010; Raven and Gregersen, 2010; Verbong et al., 2001). However, in contrast to this body of literature the focus in this paper not solely socio-technical, and hence, does not follow the multilevel perspective or strategic niche management system analytical perspective to study niche development at system level. Following Geels' comment on raising more attention on agency in niche development processes (see Geels, 2011) we rather focus on stakeholder characteristics, interactions and 'games' at the local (project) level.

The paper aims to contribute to a further understanding of demonstration projects in which green gas is produced from co-digestion. We focus here on the stakeholders' perspectives, and try to identify the barriers they may experience. In such a multiple stakeholder environment it is particularly important to safeguard the public interest. We apply stakeholder analysis to generate knowledge about the actors in green gas demonstration projects – "so as to understand their behaviors, intentions, inter-relations and interests; and for assessing the influence and resources they bring to bear on decision-making or the implementation process" (Varvasovszky and Brugha, 2000). This approach methodologically fits the 'backward mapping' approach (Elmore, 1979) and other types of 'bottom-up' research, which is commonly used by policymakers and their advisers. In policy studies stakeholder analysis is often used as a heuristic tool to analyse and structure multi-actor societal and policy issues (e.g., Dunn, 2008), especially when one is confronted with so-called 'wicked problems' (Rittel and Weber, 1973) or 'poorly structured policy problems' (Hoppe, 2010), in which complexity and stakeholder interdependency are high, and the goals and means for achieving policy targets are diffuse, or even controversial. In this article, we take a critical policy perspective stance.

The article is structured as follows. Section 2 presents the research methodology. Section 3 provides a literature review of green gas niche development. In this section we also conceptualize the green gas value chain, and define 'green gas demonstration projects'. In section 4 we present the results of our stakeholder analysis. We identify the key stakeholders and address their roles, positions in the green gas value chain, perceptions, and main problems. In the final section we draw conclusions from our analysis and provide advice to policymakers to develop strategies on how to overcome the barriers identified.

2. Methods

A stakeholder analysis was applied to agricultural green gas demonstration projects, notably the 'BioNOF' case in the Netherlands. The reason for selecting this case was that it presented the most prominent green gas demonstration project in the Netherlands at the time when data collection for this study was planned (2011-2012). In order to find out whether problems experienced in the 'BioNOF' case resemble typical problems occurring in other agricultural biogas co-digestion demonstration projects, data were also collected from other projects in the Netherlands, such as 'Heeten', 'De Marke', and more recently 'Noord-Deurningen'. Albeit its unique case study character we do not consider 'BioNOF' a standalone case in terms of stakeholders' views, interests, positions, inter-stakeholder resource exchange, and experiences.

Our analysis is based on 39 interviews with green gas experts in the Netherlands. The majority of the interviews were conducted face-to-face, and some interviewees were contacted more than once. Interviews were conducted with persons representing different stakeholders in the green gas production chain system, including energy producers (8; farmers), energy companies (6), grid operators (6), municipalities (5), consultants (2), provincial government (3), ngo's (3), potential end-users (1), national government (3), knowledge institutes (1), and producers of biogas production installations (1). For the interviews we used a semi-structured questionnaire with open-ended questions. The questions addressed the roles and positions of stakeholders within the green gas production chain, the stakeholders' goals, (access to) resources, collaboration between stakeholders, ways to organize green gas demonstration projects, ways to exercise power in decision-making, problems experienced in operational projects, and windows of opportunity for green gas niche development. Next to conducting interviews site visits to agricultural biogas production plants were undertaken. Data were collected between 2011 and 2012.

It was only after the data collection that the authors decided that five primary stakeholders for regional green gas demonstration projects were to be analysed: producers of biogas (in this case dairy farmers), energy (gas) grid operators, energy companies, end-consumers, and local governments.

3. Green gas from manure-based anaerobic co-digestion

In the Netherlands, anaerobic co-digestion with manure is defined as: "the micro-biological conversion of animals' excrements with co-substrates into biogas and digestate" (Agentschap, 2011b). In this paper green gas is defined as 'biogas which is upgraded to natural gas quality standards', and we only look at green gas which is upgraded from biogas produced from farm-scale co-digestion. Fig. 1 is a schematic of the green gas value chain, which is central to our paper.

Central to a biogas plant is the anaerobic digester where microbes convert manure and co-products into biogas and digestate. The second product, digestate (processed manure and co-products), can (theoretically) after stabilization be used as an organic soil amendment or a fertilizer (Geels and Raven, 2007). The digestate can be sold as manure depending upon the composition of the input sources (IPCC, 2011).

Biogas is produced from anaerobic digestion of manure and co-products (which increase methane production during the anaerobic digestion process). The addition of co-products - organic waste sources (e.g., fish oil, slaughterhouse residues, or maize) - increases biogas yields, and therefore makes the process more profitable, and thus more attractive for farmers to take on biogas production as a sideline to their farming activities. In the Netherlands, not all organic sources are allowed as feedstock for co-digestion. Central government has issued a limitative list of substances and sources that can be used: the so-called 'positive list' (Agentschap, 2011b). As of 1 January 2013, a voluntary certification system for co-digestion feedstock is also in force. Putting waste in biomass sources legislation is an effort taken by both the Dutch and European governments (Mckay et al., 2006) but has proven a challenge.

In 2011 biogas was produced at some 113 locations in the Netherlands. The scale of the digestion sites ranged from small (<135 Nm^3) to large (>270 Nm^3) (Agentschap, 2011c). Since their introduction biogas installations have become substantially larger, and more complex, (RIVM, 2010). There are four ways to transform biogas to useful forms of energy (Bekkering et al., 2010): (i) production of electricity; (ii) production of heat; (iii) production of heat and electricity; (iv) upgrading to green gas and injection in the gas grid. Before biogas is used, contaminations need to be removed (especially corrosive hydrogen sulfide).

Because many biogas production sites are located in geographically remote areas, far away from heat load (demand) centers, and on-site applications are often absent, direct (local) use of low-caloric heat from raw biogas is usually (economically) difficult. Therefore, biogas production from co-digestion with manure is (still) not profitable, and most plants operate with financial support from the Dutch government. Until 2012 government support (by means of the MEP and SDE schemes) only applied to 'green power' production. The schemes offered a fixed yield price per kWh produced, and were not responsive to cost fluctuations (which is attractive if production costs do not exceed the fixed yield price). Government support for heat production and green gas production from biogas only started into existence in 2012. As a consequence, before 2012 the only feasible alternative was injecting the produced biogas into a locally operating gas motor or CHP engine for electricity (and heat) production.

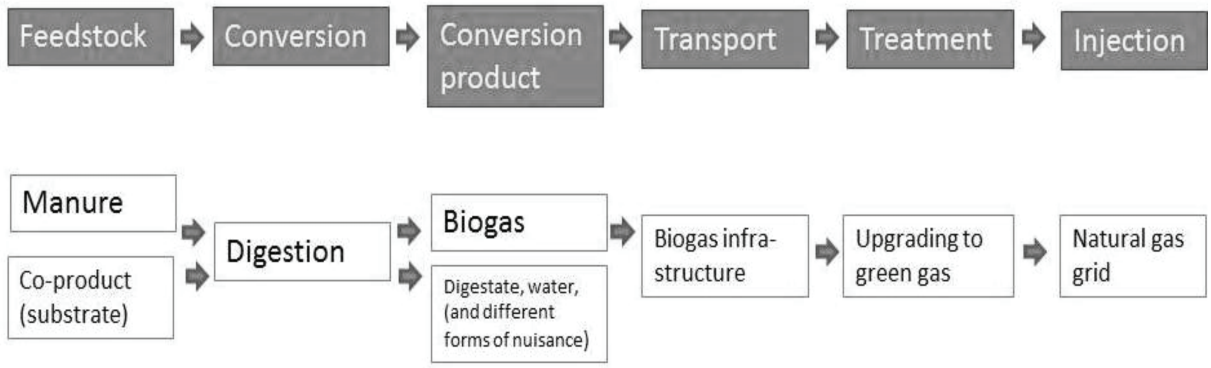

Fig. 1. Green gas value chain

The excess electricity produced was then fed directly into the grid. Using biogas for electricity generation is considered a very inefficient way to utilize biogas and produce energy (for the yield is only 40%). Upgrading to green gas and injecting into the natural gas grid is considered much more efficient (the yield is approximately 80%) (Rabobank Food & Agri, 2013), and offers greater added value (also due to the many ways in which it can be used). For green gas production, all producing activities can either be done at one large central location (which we call 'model 1' in this paper) or at multiple, decentralized locations (which we call 'model 2') (Bekkering et al., 2010).

All current operational green gas plants in the Netherlands (thirteen in total) are based on 'model 1', and feature other production feedstock than agricultural animal manure (e.g., landfill organic feedstock or sewer sludge). Theoretically speaking, expectations for green gas production are positive if significant economies of scale can be achieved with multiple cattle farms producing biogas, transporting it to a central location, where it is upgraded into green gas and injected into the natural gas grid. As compared to 'model 1' this allows for profitability in agricultural areas with vast amounts of surplus manure. For this reason, 'model 2' is considered a realistic future model by central government and the regional gas grid operators. Several regional demonstration projects have been set up to test the feasibility of this model. We consider the 'BioNOF' case a striking example.

An important precondition to making 'model 2' work, is the development of a 'biogas infrastructure'. In the 'BioNOF' case this takes the form of a low pressure gas pipeline, which allows multiple farm-scale biogas production plants to be connected to a central location, where biogas is upgraded from biogas to green gas standards (in terms of chemical composition, caloric value, Wobbe index, and pressure; Schoemaker, 2012), and then injected into the natural gas grid. As a rule of thumb, green gas production sites require an annual production of at least 5 Million Nm^3 gas to cover the costs for upgrading biogas to green gas (Rabobank Food & Agri, 2013).

Because such biogas infrastructures are not regulated under the provisions of the Dutch Gas Act, there is no pre-determined legal owner (in contrast to other countries, like Germany). Hence, stakeholders, who could potentially benefit from the biogas infrastructure, are left to decide on the distribution of the investment costs (for instance, between a number of potential biogas producers, the regional gas grid operator and an energy company). Furthermore, biogas infrastructures are not regulated in the Netherlands. As a consequence – theoretically speaking - anyone is allowed to construct, operate, maintain, and exploit biogas infrastructures (in contrast to natural gas infrastructures, which are legally reserved to gas grid operators). Because of potential negative environmental impacts, permits have to be requested by the owner(s) of the biogas plants and biogas infrastructure. The legal issuing authority for permit requests for 'model 2' plant sites is the municipality. Large-sized plants typically also require exemption from current country planning regulations, which also requires the involvement of regional government (the 'province') in the permit request procedure, with a consequent increase in complexity.

4. Results and discussion

Five key stakeholders were identified in the regional green gas project arena: (i) biogas producers, (ii) the gas grid operator, (iii) the energy supply company, (iv) end-consumers, and (v) local government. These stakeholders are active in consecutive links of the green gas value chain: livestock farmers produce and upgrade biogas into green gas, the grid operators transport green gas, and the energy company supplies green gas to the end-consumer who uses it.

Local government grants permits for biogas plants and infrastructure. If regional green gas demonstration projects are to be successful it is necessary for these stakeholders to interact, align visions, design operational plans, negotiate and exchange resources. In the next sub-sections for each stakeholder we address: expectations about the assumed advantages of engaging in green gas business; the stakeholder's role in the green gas value chain, use and access to resources; and experienced problems and challenges.

4.1. Biogas producers

Biogas production is an interesting proposition to intensive livestock farmers. In our case study the farmers concerned are dairy farmers with surplus manure, for a variety of reasons. First, biogas production offers a sideline to farmers apart from their primary economic activities, with potential economic benefits.

Biogas production allows them to monetize their manure surplus, which was previously only considered a burden, due to its mandatory disposal (involving high costs) due to strict manure regulations which severely restrict the use of manure as fertilizer on agricultural land (for soil protection). Costs for transport and disposal of manure are substantial (e.g., between €4 - 8 per Nm^3 for liquid pig manure) (Agrimedia, 2012). Second, using organic residues, especially manure, allows farmers to capture potential methane emissions and emissions of other Greenhouse Gases (GHG's), before they are emitted into the air. Given the recent attention to climate mitigation, policy schemes have arisen that encourage farmers to actively lower GHG emissions. The agricultural sector's representative body is participating in a multilateral agreement with central government on the limitation of GHG emissions, in particular methane which is considered exceptionally harmful (Min. VROM, 2007). Methane capture also fits in well with new manure policy, which compels farmers from livestock-intensive regions in the Netherlands to monitor and record their manure disposal, utilization and emissions (Min. EL&I, 2011b).

In order to achieve economies of scale (and thus to run a profitable business) a sufficient number of farmers need to collaborate. They need to organize themselves into cooperative business enterprises (which could well be related to a dairy or manure cooperative), and decide, for instance, on the resources needed (in terms of manure, co-products, and manpower), how to organize the logistics (most likely by hiring a transport subcontractor), how to transport the produced biogas, and how to allocate costs and benefits. Following this line of argument, it comes as little surprise that it is often farmer co-operatives (and manure transport contractors) who start up and run biogas production plants (Andringa and Hoppe, 2012). Furthermore, potential biogas producers need to formulate a strategy for speculating on and purchasing sufficient co-substrate materials.

Since the purchase and speculation on co-product stocks occurs at a large scale (especially in Germany, with its heavily subsidized biogas plants and profitable feed-in tariffs for green power), negative spillovers to other markets have occurred. In particular, the negative pricing effects on feedstock and food markets (due to extensive maize crop cultivation) have drawn adverse attention to energy production from co-digestion (Natuur en Milieu, 2011). Furthermore, due to a shortage in the supply of, increased market demand for, and price speculation on co-products, substrate prices continue to rise rapidly. More generally, costs for co-feedstocks, such as maize, have risen over the years, which in turn have had a negative influence on the financial viability of biogas and green gas projects (Rabobank Food & Agri, 2012). Several biogas projects in Germany were closed down for this reason in 2012 (Rabobank Food & Agri, 2013).

Besides the problem of rising co-product prices, there are many operational problems. First of all, up-front investments in the (co-)digestion installation are high: between €4.6 million euros (E-Kwadraat, 2008) and €5.5 million per plant (Agentschap, 2011c) in 2008. Other capital investments are needed besides the (co-) digester, such storage capacity for manure, substrate materials and digestate; pre-processing installations; and innovative livestock barns that permit the quick capture of manure (to prevent loss of methane, and hence loss of biogas yield). Apart from the physical infrastructure, skilled personnel need to be hired before biogas plants can commence operations. All of this requires bank loans and credits for the up-front investments. Since 2011, it has become very difficult for cattle farmers to access bank loans because of the strict standards banks have started to apply to credit lending for renewable energy projects (fearful as the banks are of uncertainties, especially profitability).

A study by Rabobank Food & Agri (2011) on behalf of the largest credit supplier in the the Dutch agricultural sector, (Rabobank) estimated that two-thirds of all manure (co) digestion plants are unprofitable in operation. Central government subsidies in the Netherlands (from 2003 MEP, from 2008 SDE, and from 2011 SDE+) are used in compensation. Notwithstanding its obvious benefits, the SDE+ subsidy scheme also features some significant uncertainties for potential farm-scale biogas producers. As there are many requests for the subsidy, a strict selection procedure is applied, following the rule that renewable energy has to be generated at the lowest cost. This disfavors green gas projects as the unit production costs are relatively high compared to alternative renewable energy routes (especially solar). Furthermore, the SDE+ selection procedure tends to prefer large-scale plants over small ones. In other words, if subsidy requests are to be successful, potential biogas producers (and other participants) have to collaborate and request the subsidy jointly, since individual requests stand little chance. Moreover, the grant of a subsidy does not automatically mean that biogas producers can start building their plants. According to Rabobank Food & Agri (2012) “a large majority of SDE+ 2011 biogas and green gas projects have tendered for and been granted support at too low a level to be financially viable. As a result these projects will not be realized …”. “Part of the (SDE+) budget is thus consumed by projects that are not going to be able to attract financing ….” More generally, Rabobank is highly skeptical about the futures of biogas and green gas. In fact, the bank has even decided to drop these modalities from its future renewable energy investment strategy. As a consequence, it will be (even more) difficult for livestock farmers who want to start producing biogas to get a loan from Rabobank.

Besides a subsidy, the entrepreneur who wants to start a biogas plant (for reasons of economies of scale, this is typically a ‘model 2’ plant) also needs a permit for (i) construction, and (ii) use. This applies to the issue of selecting the digester’s location, which takes into consideration suitability in terms of physical planning, acceptable traffic conditions, energy-efficiency, and economic feasibility (LTO, 2005). The larger the digester the greater the chance that these conditions will not be met. Although farmers are permitted to run small-scale digesters on their own property, they are not allowed to build large-scale digesters, since these can only be established on specially earmarked industrial parks, for environmental and safety reasons. In practice this is a major problem, as established firms located on industrial sites are reluctant to accept digesters near them for reasons such as image and nuisance caused by traffic movements (Noordelijke Rekenkamer, 2013). As a consequence, in some regions it is nearly impossible to find suitable locations for building biogas digesters. As a consequence, promising local ‘green’ initiatives, like the ‘Zijldijk’ case in the province of Groningen, have been terminated (Noordelijke Rekenkamer, 2013).

The entrepreneur, of course, is reluctant to incur investments before the permits are granted. In practice, the permit granting process is considered (by the entrepreneurs concerned) to be quite complex (CCS, 2010) and not without risk. Permit granting processes can cause serious delay to plant construction. There are two aspects to this problem. First, as with other bio-energy applications, municipalities do not yet have specific biogas or green gas policies in place. As a consequence there are few staff, trained and specialized in how to deal with permit requests for co-digestion plants (van Gestel, 2006). Hence, there is often a lack of expertise. Furthermore, the physical planning requirements are quite strict (as biogas production and green gas upgrading are not considered ‘agricultural activities’), which thus cuts the number of available, potentially suitable sites. If a site does not meet the criteria, then a procedure to gain exemption from the local physical planning has to be initiated (Agentschap, 2011b), which itself is a rather complex procedure, and therefore time consuming. The second problem is related to the first.

The permit procedures leave ample room for legal appeals. This can form a substantial problem for the entrepreneur, since many people living or working near the plant will oppose its construction and operation for reasons that have to do with nuisance, such as: (i) an aesthetic misfit with the surrounding landscape (due to the shape of the digester and storage tanks); (ii) transport movements necessary for the transportation of co-products and digestate are noisy, may block the typically narrow roads in rural areas and cause additional maintenance due to road erosion, and may cause leakages of potentially harmful substances; and (iii) the plant itself may emit substances that can cause unwanted odor in the neighboring area (Agentschap, 2011b). In recent years, many permit requests for the construction of biogas plant have encountered considerable resistance from local communities, who opposed construction in their immediate neighborhood. In two cases (‘Texel’, 2007; ‘Coevorden’, 2012), opponents of the grant of a permit filed their cases with the Council of State (‘Raad van State’ in Dutch), which were approved, leading to case-law (i.e. the ‘Texel’ case, stating that digesters do not automatically comply with agricultural planning regulations, which makes a legal exemption procedure mandatory), which in turn put several biogas projects on hold (Boerderij, 2008).

The legal appeals by local residents are not made without reason, since biogas production is associated with serious risks to safety, health and the environment. Due to the increased price of maize, entrepreneurial activities have spread to markets formerly not known for co-feedstock supply to co-digestion (such as slaughterhouse wastes and other animal organic materials). This is potentially very dangerous, due to the risk of chemical reactions producing hydrogen sulfide. In 2005, in Rhadereistedt (Nordrhein-Westfalen, Germany) three biogas plant workers and a truck driver were killed in an accident at a biogas production plant due to exposure to volatile hydrogen sulfide (Schmitz, 2005). Besides the danger to on-site personnel, biogas plants may also pose a hazard to their direct surroundings. In February 2012, a biogas plant in Coevorden, the Netherlands, caused odor nuisance in a residential area located directly adjacent to the plant. The odor was caused by leakage of hydrogen sulfise from the co-digestion installation. In response the local authority decided to pre-emptively evacuate all residents living in the nearby residential area. The case was broadcast nationally on public television (KRO-Reporter, 2012).

These events raise questions as to whether it is prudent to allow livestock farmers, whose farm is located in the direct vicinity of places where other people live and work, to speculate on organic co-feedstocks and produce their own chemical substrate mix for anaerobic digestion. As a consequence of accidents like this, the Dutch central government launched an enforcement pilot project (VROM-Inspectie, 2011), which has shown that, although most biogas producers are compliant, some rule violation does occur, while knowledge of co-digestion feedstock mixing is considered ‘complex’, and therefore difficult to understand and apply in operational management. In January 2013, enforcement was intensified (by means of spot sampling checks on co-feedstocks and digestion mixtures). Farmers who violate the regulations face suspension of their subsidy grants, recovery of previously paid subsidy money, or withdrawal of their permits to produce biogas. 2013 was considered a ‘pilot year’: If the results had only a limited effectiveness (i.e., too many rule violations), the policy for co-feedstock materials subsidies would be reconsidered (Vermaas, 2013).

Once the plant is built, operational management demands a lot of time and attention from the entrepreneur. Government campaigns, designed to convince farmers to start producing biogas, often downplay or neglect this aspect. The installation, in particular the microbial colony, needs time to become active; once operational it needs almost constant feeding with manure and co-products to remain operational. Moreover, the plant needs to run at full capacity.

The co-digester is vulnerable to different forms of pollution (such as plastics, sand, twigs and stones) that may end up in the feedstock and risk ending the chemical biogas production process, which leads to weeks-long loss of income. In sum, the biogas plant requires specific knowledge from the entrepreneur about its operational management. This aspect is often underestimated.

Once the gas has been produced, the biogas needs to be transported to a central location for upgrading to green gas. The plant owners need to decide how to divide the up-front investment and maintenance costs for the biogas infrastructure and biogas upgrading installation. Moreover, they need to get permission from the regional gas grid operator to be allowed to inject green gas into the (conventional, natural) gas grid. This requires the producers to meet green gas quality standards (such as the right methane content, Wobbe index, calorific value, and pressure), which requires investments in material for feed-in following the rules set by the regional gas grid operators. Such investments include: measurement equipment, connection to the central gas grid, odorisation, gas conditioning, and compression to the required pressure (de Bruijn, 2011). Costs for feed-in are between €340,000 and €900,000, assuming feed-in of 550 Nm^3 green gas per hour on an 8 Bar gas grid (de Bruijn, 2011).

Collection and treatment of decentrally produced biogas can be problematic and expensive when biogas derives from multiple production plants. Due to the relative freedom biogas producers have in using co-products it comes as little surprise that biogas streams with varying chemical compositions are delivered for centralized upgrading to green gas. This requires expensive pre-treatment before injection to the gas grid. This, in turn, leads to uncertainties, difficult decision making processes, and stress in relation to cost distribution among biogas producers, the gas grid operator, and (in some cases like 'BioNOF') energy companies.

4.2. Gas grid operators

Under the Gas Act, gas grid operators are solely responsible for the construction, management and maintenance of gas grids. Following the liberalization of the Dutch energy sector, gas grid operators have regional monopolies, and are therefore closely controlled by the Dutch anti-competition authority NMA, which strictly limits the gas grid operators' operational and strategic marketing activities, to prevent them from raising tariffs for gas transportation and connections to the gas grid.

Nevertheless, there many reasons why green gas injection to the gas grid is an interesting proposition to the gas grid operators (recall that green gas does not have to come from biogas producing farmers, but also from other producers, such as sewage plants and landfill operators). Green gas offers a new niche market for the gas grid operators. Compared to local biogas applications, green gas offers the benefits that it can be mixed with natural gas and used throughout the country. More generally, not being limited to local use offers economies of scale, and thus offers an interesting proposition to the gas grid operators. As mentioned in section 1, there are high expectations about the growth of the green gas market. Therefore, there is a belief that investing in green gas development now will offer future market benefits as gas grid operators become early-market pioneers in green gas. This allows them to learn now and gain a competitive advantage. In that way, current investments in green gas demonstration projects can be perceived as strategic investments, which will offer positive returns in the long run.

Although green gas offers benefits, the gas grid operators also face many barriers. First, there are operational problems, such as the injection of green gas into the natural gas grid. The fact is that there is too little capacity in many places in the natural gas grid to inject the full green gas capacity throughout the year.

One can only inject as much gas into the grid as the amount that goes out (during a 24-hour day; variation between parts of the day is possible, though). Furthermore, demand for gas is not stable throughout the year. Demand is lower in particular during the summer than in winter, and is more intermittent. As a consequence, green gas suppliers run into problems because they produce fixed quantities. "The microbe populations in the digester cannot just simply switch off" (Stichting Groen Gas Nederland, 2011). Second, since gas quality for injection in the natural gas grid needs to meet legally prescribed standards, it is important that biogas producers supply biogas of comparable (or rather, fixed) chemical composition. In practice, this is rather difficult because biogas producers are allowed – within the boundaries of the so-called 'positive list' of co-products - to select co-products for anaerobic digestion themselves. Due to the co-products' scarcity, price-rises, and speculation there is variation in the feedstock processed for biogas production by different producers. Regional gas grid operators are thus very dependent on the quality of green gas delivered by the producers.

There is a legal issue resulting from the provisions of the Gas Act that constrains gas grid operators in their efforts to operate biogas infrastructures. Construction, management and maintenance of biogas infrastructures are not considered a 'non-regulated task', but a 'non-regulated activity', which implies that gas grid operators operate as market parties when it comes to transport of biogas in biogas infrastructures, and not as semi-public utility organizations (which is the case when they transport only natural gas, their actual, legally prescribed function). In practice, this means that gas grid operators are not permitted to finance biogas activities from their regular activities. Exploitation of biogas infrastructures hence requires them to use competitive market prices. From a financial-economic perspective this is unfavorable, which leads gas grid operators to depreciate their investments within short periods. As a consequence, the additional costs lead to higher green gas prices, which in the end are also passed on to the end-consumer. In the meantime, the gas grid operators must guarantee that the green gas quality meets natural gas standards in order to provide end-consumers with the quality standards of natural gas. Failure to meet the regular quality standard will lead immediately to a loss of credibility for green gas as a substitute for conventional natural gas. Furthermore, a legal permit is required to ensure that green gas meets natural gas standards to avoid hazardous and other harmful situations.

The distribution of the investment costs in the biogas infrastructure is of major importance to the green gas demonstration project. In contrast to Germany, it is not just the gas grid operator who is expected to make the investments required, and who is responsible for operational management and maintenance. In the Netherlands, other potential beneficiaries of the biogas grid are also expected to share the burden. In the 'Bionof' case a practical solution was found to resolve this issue. The biogas pipeline is to be constructed, managed, and maintained by the gas grid operator as an 'unregulated activity' (outside the scope of the Dutch Gas Act). The biogas pipeline will be owned by the gas grid operator. Until the pipeline is operational, the gas grid operator puts up half of the investments with other participants. Once the pipeline is operational, the grid operator participates in a joint venture. The contract partner in the joint venture is the energy company, which books transport capacity and rewards the joint venture with reasonable compensation. This financial solution theoretically lowers the threshold for gas operators to invest in uncertain projects and technologies, like green gas (something which they have become more reluctant to engage in, in recent years).

Participation in green gas projects is, however, not just a decision gas grid operators take only from an individual financial-economic business perspective. Governments also have a majority shareholding, and are theoretically in the position to exercise 'public share ownership, and hence influence decision making, including corporate strategy. In reality, however, governments are hardly involved in the operational and strategic management of regional system operators.

4.3. The energy company

First of all, energy companies should be viewed for the purposes of this paper as 'energy traders', not producers, since as they only buy and sell green gas. The most important reason for them to participate in green gas projects is that green gas can be perceived as a potentially profitable side-line: green gas as a sustainable alternative to natural gas. Energy companies nowadays face external drivers that encourage them to consider green gas as an important alternative to their prime business. In the years to come the European Union will urge energy companies to produce, (or) buy and sell increasingly larger shares of renewable energy. Moreover, selling green gas could be financially and economically interesting to energy companies for their trade in 'green certificates' (or 'bio-tickets' in case green gas is used for mobility purposes) (ECN, 2012), although they are not designed to cover more than just unprofitable investments. Like other emission certificates, energy companies can sell these certificates (with CO_2 emission rights) to potential polluters elsewhere. Furthermore, green certificates also allow energy companies to speculate on the carbon price market. It is not surprising, therefore, that it is energy companies that are initiating and leading large-scale green gas demonstration projects (such as the 'BioNOF' case). Energy companies are currently in the position to gain a (competitive) lead over their peers by participating in green gas projects. Moreover, the energy companies' expectations match the Dutch government's energy transition vision, in which the green gas innovation route is well positioned. Another reason for participating in green gas projects stems from corporate social responsibility. It is seen as way to project the company's 'green image', and helps with branding to ecologically oriented customers, who might be inclined to buy their gas, which will be perceived as 'clean' and 'reliable'.

Besides the expected benefits, energy companies also face barriers. First, the energy companies are not clear about what they can expect from the gas grid operators. In principle, they want to involve the grid operators because of their expertise and know-how in the safe, efficient operation of (bio-) gas grids. This, however, is rather a false expectation as the grid operator is legally not permitted to act as a public actor (because the biogas grid is not a gas grid according to Dutch law) and apply the public competence to the operation and management of biogas grids, in contrast to what it does when operating conventional natural gas grids. For this reason, gas grid operators are expected to construct, operate and maintain biogas grids under market conditions (since this is a 'non-regulated activity').

In practice this makes it difficult for energy companies to enter into business negotiations with gas grid operators. Second, like the gas grid operators, energy companies depend on cattle farmers to produce biogas. They have to cope with the uncertainties their contract partners face (upstream in the green gas production chain). Third, energy companies have to beware that the green gas price (the price for which they sell to end-consumers) will not get too high, especially since it is already more expensive than conventional natural gas.

4.4. The end-consumer

End-consumers are interested in using green gas for its potential price advantages – especially when they consider that the future price of conventional natural gas will rise, as well as the 'green' image green gas offers. Although awareness of renewable energy is increasing among citizens, it does not mean, however, that the large majority are sufficiently well informed. Since the liberalization of the energy sector, end-consumers have been to buy energy from their preferred energy company. Basically, therefore, the end-consumer is empowered to select the energy company that promises the cleanest green gas (in the gas mix) for the lowest price, comparable to buying 'green electricity from a generating company. Because green gas is injected into the conventional gas grid, it can be utilized throughout the country. Like natural gas, green gas can be utilized for central heating of living spaces, or water, or for cooking. Green gas can alternatively be used as a fuel for gas-fired cars.

Alternatively, and if the location parameters are right, end-consumers can also be in a position to purchase locally produced green gas (or alternatively biogas, with modifications to their gas boilers). Green gas could also be utilized as fuel for district heating in residential areas or business parks, and for combined heat and power (Krozer et al., 2008). Local production and use of green gas in a district heating scheme might be useful to achieve high energy efficiency performance in residential dwellings. Once these dwellings are connected to the green gas-fuelled district heating system, they might be awarded an energy performance certificate, which indicates the dwelling's high energy efficiency potential, and indirectly positively influence the dwelling's market price. This could be a driver for (future) home owners to connect.

Nonetheless, in the case of neighborhood development and other forms of new housing construction, home owners and tenants depend on project management, municipal officials and project developers whether their dwellings are to be connected to a green gas grid or district heating system. Furthermore, district heating brings with it the end-consumers' norm of 'not paying more than in any other case' (e.g., the natural gas price). When green gas prices rise (e.g., due to the increasing prices of co-products), it might leads to financial feasibility problems when end-consumers start to demand that they should not pay more than usual. Finally, there are local opportunities with firms organizing to collectively purchase green gas for local use on business park sites (in park management contracts).

4.5. Local government

Local governments play an important role because they grant (or do not grant) permits for the construction and use of farm-scale biogas production plants. This is of great importance, because it is known to be one of the major barriers to the development of local bio- and green gas projects. Failures to grant permit requests mostly have their origin in legal appeals by stakeholders who live or work nearby the (planned) biogas plant, due to their fear of potential nuisance (such as malodor, noise, or spoiled outlook). Failures to grant permits are often blamed on civil servants who lack detailed (regulatory, technological) knowledge, or requests interpreted in rather latitudinarian ways. Furthermore, there may be organizational problems within local governments. Public officials from different departments (the environmental and finance departments, for instance) may have divergent goals, which are incompatible, thus leading to conflicts which turn out to be disadvantageous to decisions on green local gas initiatives. Green gas utilization is interesting to local governments because it contributes to the achievement of their climate policy goals (meeting previously set political goals in terms of CO_2 emissions prevented). There are two ways for them to do this: first, by adopting measures to utilize green gas themselves or, second, to encourage utilization of green gas by local stakeholders. More generally, local governments are in the position to create a substantial local demand for green gas.

The guiding theory in this case is that creation of a sufficient degree of market demand will automatically cause the local green gas supply to follow. In order to achieve this, local government could deploy several policy instruments: support of entrepreneurs in the legal procedures for requesting a permit, granting investment subsidies, information campaigns, addressing green gas utilization in project development, and by encouraging the collective utilization of green gas in business parks (park management, which has the advantage of demand-side economies of scale). Furthermore, green gas projects, like other renewable energy projects, are often used by local governments to gain public attention and exposure. In the 'BioNOF' case, for instance, the municipality of Leeuwarden used the green gas case extensively to position itself in the 'Energy Valley' network of the Northern provinces.

Finally, local governments may be in the position to support green gas projects as a (public) shareholder in gas grid operator companies, which – theoretically - offers opportunities to influence corporate decision making and budget allocation to green gas projects.

4.6. Discussion

In sum, there are many operational, financial-economic, environmental, safety, legal and - administrative limitations that block the success of agricultural green gas demonstration projects. Most stakeholders are striving to achieve their own goals – foremost among them being maximizing their financial-economic gains.

However, they depend firmly on each other. For most of them, green gas production and distribution is still unprofitable. Therefore, subsidies are (and remain) necessary as financial compensation (both investment subsidy and feed-in tariff subsidy), and collaboration is a *conditio sine qua non*. Due to a plethora of uncertainties, stakeholders are reluctant to invest their capital in projects, especially the biogas grid, which still is legally unregulated. For potential biogas producers this can easily be understood, as they face the lions' share of the investments and uncertainties, so they are reluctant to invest, and nothing happens. The Dutch legal framework (in this case the Gas Act) – in contract to other countries, notably Germany – does not, for instance, compel the grid operators to construct new pipelines when a new producer wants to inject green gas into the conventional gas pipeline.

Given the barriers we have identified, green gas from farm-scale co-digestion emerges as a niche that cannot easily 'be left to the market'. If the niche is to become viable, and goals like those set by the grid operators in 2012 are to be attained, policy change is necessary as stakeholders currently lack the incentives to develop the green gas niche on their own.

Following the problems identified we formulated policy recommendations that could enable the respective stakeholders to cope with these problems. An overview of the key problems and policy recommendations per stakeholder is presented in Table 1.

5. Conclusions and perspectives

The aim of this paper was to contribute to an understanding of demonstration projects in which green gas is produced by livestock farmers via biomass co-digestion. We have focused on the stakeholders' perspectives and identified barriers accordingly.

Furthermore, we were interested in discovering whether public interests are safeguarded in the production and supply process of green gas. We applied a stakeholder analysis to identify key stakeholders, their motivations, resources, interrelations with other stakeholders, and define problems they face when engaging in the green gas production chain.

Table 1. Overview of key barriers experienced per stakeholders, and policy recommendations based on those

Stakeholder	*Experienced barriers to engage in green gas production chain activities*	*Policy recommendations*
Biogas producers (live stock farmers)	1) Collaboration between multiple livestock farmers is required to realize economies of scale production. Involving more of them in collaboration efforts, however, increases complexity in decision-making. 2) Negative spillovers to food markets (due to use of particular crops as ingredients for co-digestion). 3) Substantial price increase of particular co-feedstock deemed essential for co-digestion. Related to heavy regulation on co-feedstock allowance in co-digestion production. 4) Need for substantial upfront investments and maintenance costs. At the same time increased difficulty to attract loans from banks. 5) Operational management of production plants is time consuming, requires specialized knowledge and skills; hence, it is more than just the side activity livestock farmers expect. 6) Uncertainties that go with the SDE+ subsidy scheme allocation system. 7) Potential harm to humans, animals and the environment (incl. diffusion of cattle diseases via transport of organic co-feedstocks to and from central co-digestion plants). 8) Increased difficulty to get required legal (environmental) permits due to increased spatial zoning restrictions and room for legal appeals by local community members resisting construction and operation of biogas plants in their 'backyards'. 9) Costs and risks that go with collection and centralized treatment of biogas and feed-in of green gas to the gas grid. Grid operators determine the conditions to which biogas producers need to comply, and have ample incentives to make investments themselves. This results in unequal financial burdens and risks in up-front investments to biogas producers. 10) Uncertainties related to investments and profitability of biogas infrastructures. They need substantial upfront investments, and livestock farmers cannot be expected to make the investments alone.	1) Use of a collective investment fund to solve problems regarding the upfront investment 'deadlock' in biogas production, treatment equipment and biogas infrastructures. A public investment fund could help to increase investment conditions. 2) Development of business and organizational models that convince and support livestock farmers to start collaborating in green gas projects with sufficient substantial economies of scale concerning biogas production, whereas costs and benefits are shared equally between project partners. Process-, network- and transition management (alignment of visions, experimenting, learning, management of expectations) is key in joint efforts. 3) Development of a program about knowledge provision and training of livestock farmers on how to manage and operate biogas production plants. 4) The SDE+ subsidy scheme needs to give more opportunities to small-scale (and collaborative) biogas production plants. Furthermore, policy makers should let go of the 'lowest cost per unit of renewable energy produced' rule that applies to the SDE+ scheme, since this does not stimulate innovation, in particular vis-à-vis agricultural green gas production. 5) Development of regulatory or tax incentives that allow for affordable co-feedstock. 6) Development of procedures and training of local government civil servants to deal with permit granting for biogas plant and infrastructure construction smoothly. In addition spatial designated areas can be assigned on which favorable conditions apply vis-à-vis construction and operation of biogas production plants.
Grid operators	1) Uncertainties related to injection of green gas by farmers, e.g. quality of green gas (e.g., chemical composition, pressure), lack of capacity in many places, unstable gas demand by consumers leading to	1) Regulation of 'biogas grids' with the Dutch Gas Act to lower perceived uncertainties about legal implications of biogas infrastructure construction and operation. 2) Clear regulation of what grid operators are allowed to

	unbalance in gas grids, lack of gas storage capacity. 2) Limited scope of actions following limitations to grid operators set in the Dutch Gas Act (as 'non-regulated activities'; hence grid operators do not operate as a public entity in biogas grids). No allowance to finance biogas activities form regular activities. A biogas grid is not a gas grid according to the Dutch Gas Act. Grid operators are, hence, bound to operate biogas grids under market conditions.	do and what not to do regarding investments, operation and management of biogas grids. Currently, there is hardly any incentive for grid operators to invest in biogas grids. Despite their skills and knowhow the role of grid operators is biogas grid management is diffuse, and perhaps unnecessarily limited. Perhaps lessons can be learnt from practices in other countries.
Energy companies	1) Dependency on grid operators and biogas producers (and hence vulnerable to price setting for biogas production, treatment and transport). 2) Green gas is more expensive than natural gas, and therefore financially less attractive to sell to end-consumers.	1) EU policy that encourages energy companies to sell more energy from renewable sources to consumers could be an incentive for (more) energy companies to enter the green gas market.
End-consumers (households and business companies)	1) Low degree of awareness. The majority of end-consumer do not care about using renewable energy, are not responsive to price differentiation, let alone switching contacts concerning energy supply. 2) For integration of green gas in residential district (re-) development plans, there is a high dependency on other sectorial interests and processes. 3) Risk to pay more than 'usual' (c.f. natural gas use).	1) Awareness raising campaigns addressing the benefits of green gas use (addressing both households and business companies looking to rent office space). 2) Demand-side innovation support policies to support use of green gas in mobility and domestic use (including 'bio-tickets, and subsidies to lower pricing when purchase cars that use green gas instead of fossil fuels, and tax benefits to those who use green gas instead of fossil fuels).
Local governments	1) Environmental risks that go along with operation of local biogas production plants, treatment and transportation of green gas. 2) Lack of knowledge among public officials and civil servants. 3) Inter-department interests conflicts that disfavor the municipality becoming a launching customer of locally produced green gas.	1) Local governments can use public shareholder-position to influence decision-making by grid operators vis-à-vis support of green gas production (e.g. investments in biogas infrastructure, biogas treatment, transport of green gas, and R&D to support green gas value chain management). 2) Local governments can train staff on how to cope with legal permit requests for biogas plant construction and operation. 3) Local governments can prioritize local green gas production and transport, and adjust (earmarked) spatial zoning accordingly.

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