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Municipalities as facilitators, regulators and energy consumers: enhancing the dissemination of biogas technology in Denmark

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ABSTRACT

Biogas provides many potential benefits relating to renewable energy production, environmental protection and job creation. However, the lack of initiatives from the national government and local municipalities hamper the spreading of biogas plants, and hence the large potential of manure, and other types of digestible organic waste materials, is not being fully utilized for energy purposes. The development of the biogas sector could be enhanced by seeing municipalities as *energy consumers* constituting a local market for biogas, as *regulators* enforcing new requirements and regulations on the biogas sector, and finally as *facilitators* assisting and helping involved stakeholders. To achieve this we suggest slimming down documentation; requiring that part of the municipal heat be provided by biogas; identifying alternative heat markets for the sale of non-upgraded biogas, and mapping new types of gas boosters etc. We conclude that the role of municipalities as *facilitators* is the most important support for biogas that local governments (municipalities) can provide.

Keywords:

Biogas,
Denmark,
energy planning,
local governments,
municipalities,
renewable energy.

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1. Introduction

In order to help compliance with global requirements and targets for greenhouse gas (GHG) reductions and the deployment of renewable energy technologies within local communities, we undertook an assessment of various analyses of how and to what extent different municipalities can engage in the transition of energy supply systems. Examples of such assessments undertaken outside Denmark are many and include investigations of how local governments can engage in the implementation of specific renewable energy technologies, and how they adapt to climate strategies in planning processes at the municipal level [1], [2].

1.1. Danish governance of biogas

Examples from Denmark include studies of how local governments can engage in the implementation of district heating, windmills, biomass and geothermal energy within local communities [3], [4], [5], [6]. However, there have been a limited number of analyses of local governments *and* governance of biogas technology. Vast amounts of literature describe biogas technology, focusing on technical issues, feedstock, GHGs and management etc. [7], [8], [9], [10], [11], and literature also exists on how municipalities can support biogas with a specific purpose, such as transportation [12], [13]. But an investigation of how municipalities more broadly can govern biogas in their renewable energy portfolio is currently lacking. Thus this paper is aimed at contributing to this discussion.[1]

1.2. Biogas in Denmark

Biogas technology has been deployed in Denmark since the 1970's. Initially this was in response to the oil crises, which led to a focus on the use of indigenous energy resources. At that time, biogas technology consisted of relatively simple farm scale plants that produced heat to

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substitute the consumption of oil on, for example, pig farms [14], [15]. Today, two kinds of biogas production are used in Denmark, namely large scale centralized biogas plants that capture feedstock from multiple sources and smaller farm biogas plants that process manure and organic waste from a single farm. Centralized plants receive animal manure from several farmers, as well as organic waste such as sludge from wastewater treatment, organic waste from the food and beverage industry, oil residues from the fish industry and organic fractions from commerce, etc. Within recent years, these plants have also begun to add different types of agricultural residues (straw, grass) and energy crops (beet, maize) to increase gas yield [7]. The main focus of this paper is on centralized biogas plants in Denmark.

The first centralized biogas plant was established in 1984; today there are approximately 25 [14]. The combined heat and power (CHP) produced is usually distributed as heat in a local district heating system or sold and distributed via a larger system in the region, and electricity sold to the national grid. On farm biogas plants, the feedstock can also include a mix of organic materials (e.g. grass, beet and maize) and animal manure, but this usually comes from a single farm. The heat is used to warm up stables and farmhouses and the electricity is distributed on the national grid [11]. Currently there are 46 farm biogas plants in Denmark [16].

The biogas produced has been utilized almost exclusively for CHP production in Denmark [16], however several new plants have been established to distribute gas on the well-distributed natural gas network [17]. Here, the biogas is upgraded in a process in which CO_2, sulphur and moisture are removed and the gas cleaned and dried resulting in a quality similar to natural gas, thereafter it is injected into and distributed via the Ngas network [7], [18]. This method is, for example, commonly applied in Germany, Sweden and in the Netherlands, and in both Germany and Sweden biogas is also utilized on a large scale within the transportation sector [19], [12]. Here, private cars, as well as fleets of, for example, city buses and refuse trucks run on biogas. The use of biogas in the transport sector requires (relatively) expensive cleaning, upgrading and compression, etc. [20], [21].

Danish biogas plants currently contribute 4.2 PJ or 0.5% to the national energy consumption, which totals around 800 PJ [16]. 60% of this energy is produced at biogas plants, and the remaining on wastewater treatment plants and landfill sites. The estimated total available manure (manure *and* available organic industrial waste) that could be treated in Danish biogas plants constitutes a potential of approximately 40 PJ of energy [16]. The Energy Agreement arrived at in 2008 states that by 2025 30% of this manure must be digested, amounting to 12 PJ [22]. In 2009, the Danish government launched its Green Growth Strategy, which proposed that by 2020 50% of the manure should be digested, providing 20 PJ of energy [23].

Achieving these political targets requires a further development of the framework conditions governing the biogas sector [24]. This must include not only enhanced national governmental frameworks, but also stronger capacity at the local governmental level through stronger municipal support [25], [26]. When focusing on the many benefits associated with biogas, emphasized further below, it becomes evident that local authorities could benefit extensively from the implementation of biogas plants within their community. So far, the many obstacles for deploying the biogas technology in Denmark have hampered a further exploitation of these benefits, the most important being: 1) A lack of organic biomass waste to increase the gas yield, 2) A relatively limited market for biogas, 3) A lack of financial loan opportunities, 4) Difficulties in locating space for large centralized biogas plants due to local resistance, 5) High plant investments and low plant profitability and 6) A long timeframe for realizing biogas projects [24], [26], [27], [28].

The benefits of biogas are however Numerous and comprise not only the production of renewable energy that substitutes the use of fossil fuels, resulting in carbon dioxide (CO_2) emission reductions, but also benefits associated with the handling of manure. Thus, GHG emissions from the agricultural sector will be reduced, more specifically from nitrous oxides (N_2O) and CH_4 (methane) previously emitted from farmland and stables, manure canals and uncovered manure storage tanks and open pits, etc. [7]. Digested manure etc. (named digestate) can, for example, provide the following environmental and economic benefits [7], [11], [29], [30]:

1) Limit odor annoyance when distributing digested manure on farm land, 2) Reduce the risks of nitrogen pollution when applying the digested manure on farm land as the crop's capacity to utilize the nitrogen increases compared to non-digested manure, 3) Increase the value of manure as fertilizer by digesting biomass containing high contents of nitrogen (NH4) together

with manure, e.g. ray grass and clover grass, 4) Lower the risk of spreading diseases by means of pathogen organism, kiim, etc., as the manure undertakes a hygenization and sterilization process during the digestion process, 4) Nutrients are recycled to farmland and assist in the buildup of the carbon stock and humus content of the soil, 5) Valuable minerals and e.g. finite resources as phosphor are recycled, and 6) Avoided expenses to purchase of artificial fertilizers are obtained which require large amounts of fossil fuel energy entailing a high carbon footprint.

The implementation of centralized and farm biogas plants can also generate new job opportunities within Danish municipalities in remote areas lacking development [31]. Manpower will, for example, be needed to produce, collect and transport organic materials to boost gas production such as source separated household waste and residual straw from farmland. The technical equipment, such as the construction of and maintenance and operation of the plant, also bring about jobs; some short term such as those associated with the construction phase, and some permanent, such as those connected with daily maintenance and operation [31], [32]. Biomass technology is, compared to other renewable energy technologies, more labor intensive and thus creates more jobs both directly and indirectly [31].

But how can municipalities more specifically support a further deployment of biogas technology within Danish municipalities in order to harvest the many benefits outlined above? Which concrete actions could be undertaken at the municipal level, and what type of activities can actually be provided at the local level to enhance the implementation of biogas technology? In order to answer these questions, we will investigate the specific opportunities open to the municipalities to support the biogas sector, and provide new knowledge of *how* and in *which* areas municipalities can strengthen their future role in disseminating biogas technology. The aim of this paper is therefore to answer the overall question of *how Danish municipalities can support the dissemination of biogas plants within their local communities*?

2. Methodology

The methodological approach applied in this paper identifies the beneficial roles of local governments (municipalities) by drawing on the work of Corfee-Morlot et. al. (2009) [25], Burkeley & Kern (2006) [33] and DEA (2013) [34]. According to this approach, municipalities, among others, can influence the biogas sector by utilizing biogas in their local energy consumption, as being energy *consumers*, by enforcing requirements and regulations on the sector through their role as *regulators*, and by assisting and helping the involved stakeholders as *facilitators*. The *planning elements* (1–4 below) related to biogas can to a greater or lesser extent, be governed by Danish municipalities. The degree to which municipalities can govern these planning elements in favor of biogas is determined by the municipalities' roles as consumers, regulators and facilitators, shown in brackets below, and elaborated further in the following:

1) Regulation and supervision (facilitator)
2) Heat planning (consumer/regulator/facilitator)
3) Physical planning (facilitator)
4) Renewable energy planning etc. (consumer/facilitator)

As an energy consumer, for instance, the municipality uses different energy services, which they can influence. Thus, they can promote the use of biogas as an energy source in the municipality through the use of biogas in their own energy consumption (renewable energy planning). Looking at the municipality as a regulator, there are also options for supporting an enlargement of the biogas sector, for example by requiring local CHP plants to utilize the biogas produced, in accordance with the Heat Supply Law (heat planning). As a facilitator Danish municipalities can support the biogas sector by improving the regulatory procedures and thus speed up the authority's work on biogas (regulation and supervision). In addition to the municipalities' role in supporting biogas, this paper also suggests ways in which the national government could support biogas, but the pivotal emphasis is mainly on the municipalities' role. The methodology applied is thus to identify – by applying the theoretical lens described above – the areas in which municipalities can support the biogas sector. The results can be utilized to guide municipalities' efforts to promote biogas as a renewable energy technology.

Data utilized throughout this paper are based on the academic literature, reports and documents from Danish authorities, as well as from consultants and researchers working within the field. Interviews have also been conducted with the above informants. Data regarding municipalities concerning regulation and supervision is based on actual project participation during the planning and implementation of a biogas plant in Denmark. The authors took part in the preparation and planning phase of the Solrød Biogas plant located on Zealand. This enabled them to gain knowledge and experience relating to how the approval process for biogas could be improved. Dialogue and communication with planners, consultants and experts within the biogas sector has subsequently strengthened the validity of the observations, and the usability of the suggestions on how to improve the process.

3. Municipal opportunity analysis

The paper now proceeds with an investigation of municipal support opportunities for biogas, applying the analytical lens described above, which is summarized at the end of the paper. Finally, we provide a discussion and conclusion of the paper's main findings.

3.1. Regulation and supervision (facilitator)

Biogas is legislatively related to agricultural, environmental, planning and energy laws, and Danish municipalities must therefore comply with this regulation in their authorities' work on biogas. For example 1) Agricultural laws such as the Livestock Manure Law provide rules for storage of manure, and the 2) Environmental Law, for example, regulates smell and leakages from biogas plants, the 3) Sludge-regulation sets the quality of waste supplied to biogas facilities, and the 4) Livestock Law provides rules for the use of biomass and digestate distributed on farmland as fertilizer. As far as planning the 4) Planning law constitutes the overall planning framework for biogas, including Environmental Impact Assessments (EIA), where energy laws include e.g. the 5) Law on heat supply, that provides rules for heat planning within Danish municipalities (see section 4.2), as well as the 6) Risk-regulation that complies with the storage of biogas [24]. The role of municipalities in regulation and supervision has so far thus primarily been limited to authority work in providing review connected to planning and environmental procedures for biogas, such as conducting risk assessments, EIA, comply with rules regarding manure distributed on farmland, provide construction and digging permits and conduct municipal and local planning, etc. [27].

In addition to the role mentioned above, the government has required the municipalities to point out relevant sites for the implementation of centralized biogas plants in their municipal planning so as to support a further development and deployment of biogas plants in Denmark. Status ultimo 2013 showed that 40 out of 98 municipalities had identified 'positive areas' for locating biogas plants in their municipal plans, and that another 30 support the implementation of biogas in their community [26]. This support is, however, primarily a statement of interest, as no real active engagement by municipalities in promoting biogas follows [28]. Hence, as far as authority is concerned the role of Danish municipalities is very clear, but further activities actually facilitating and promoting require a more active role by local governments as is emphasized below.

Engaging relevant stakeholders and acting as a platform for dialogue between local actors interested in biogas is not the concern of local governments. Danish municipalities are in general not very active in supporting biogas though there are a few exceptions such as the municipalities of Solrød and Ringkøbing-Skjern where best practice cases of biogas implementation can be found due to, for example, an active, open and stakeholder inclusive approach. Municipalities do not engage in helping and assisting potential investors with, for instance, pre-feasibility studies in the initial planning phase for biogas, or in providing guidance when it comes to the availability of local feedstock, etc. Activities related to municipalities being potential consumers of locally produced biogas are also limited, just as surveys of market expansions for biogas within municipalities are limited (for instance new heat markets and alternative distribution options for biogas).

The municipal power given by the Heat Supply Law means that local governments can require energy companies to investigate and implement certain types of energy plants, as well as local CHP plants to utilize certain type of fuels. However, these are also rarely enforced, but they could certainly benefit the biogas sector. Thus, besides a few very active municipalities, local governments mainly provide authority work [13]. Section 4 will look at how local governments can play a more active role in promoting biogas additional to the authority work, but first we will suggest how municipalities and the national government could be more supportive in their authority work.

3.2. Speed up the process

Regulatory procedures connected with the implementation of renewable energy technologies within Danish municipalities is time consuming. It may take up to five to eight years before a large scale biogas plant is actually constructed. Hence, regulatory procedures within the municipalities can account for several year of authority work, before the necessary permissions and paper work etc. are in place. Such a process is described below [26], [27], [28].

After a first 'Screening and Scoping' of a biogas proposal, the municipality needs to complete five important documents, before the necessary approvals are finalized for continuing the work. First, an Environmental Impact Assessment (EIA) needs to be conducted providing an analysis of a project's impacts on the surrounding environment. Second, a Municipal Plan Appendix is provided, as an amendment of the existing municipal plan in which they summarize and specifies key policy objectives for the further development of the municipality. Third, an Environmental Permit is made including terms regarding the use of equipment and internal function of the business and connected emissions, such as air emissions, noise, waste and self-monitoring etc. Fourth, a Local Plan is provided. This is a detailed plan with binding rules for a particular area of the municipality, and thereafter a Rural Zone Permit is made to prevent uncontrolled development and construction in the countryside and preserve valuable landscapes.

Usually, if a plant is to be established in rural areas, which normally would be the case for biogas, a Rural Zone Permit is required from the municipality to construct new buildings, to change the use of existing buildings and undeveloped land. Fifth, and finally, a Project Approval needs to be granted, as local authorities must approve heat supply projects when the heat is to be distributed on the collective heat supply system [35]. The most time consuming activities related to the above regulatory procedures are the decisions taken by the Municipal Board, as well as the public hearing periods which most often regard issues of where to place the biogas plants. The EIA and environmental approval can be a time consuming process [28], [36].

The five documents described above can be prepared separately, but the legislators – such as the European Communities guideline etc. – state that the documents should be conducted in parallel and published at the same time. But this is often not the case [36], [37]. Conducted separately, the three documents will require 93 weeks of municipal work. The same approach is suggested for the two remaining documents (Local Plan and the Rural Zoning Approval). Thus, there are no formal barriers to prevent these documents from been completed simultaneously. It would only require that the Municipal Plan Appendix should be approved before the Local Plan by the Municipal Board [28], [36], [37].

So, if all five documents were made at the same time, it would be possible to speed up the process and provide a *shorter timeframe* for the municipal regulatory procedures for biogas (41 weeks). If only the three first documents can be done as a parallel process a *long timeframe* of 66 weeks would be necessary (still 30 days faster than normal). Thus, the two last documents require 15 additional workdays to be finalized, compared to the short timeframe. In order to support the work on municipal documents, it is suggested that the municipality – in the initial stage of the process – develop an overall project report for the potential biogas plant. Thus the data for the five documents can be taken from this report consequently speeding up the process [36], [37].

3.3. New biogas approval process and flow

Thus, we suggest that the process of implementing biogas plants from pre-feasibility to realization of the plant should be conducted in three phases, presented in the following, based on the authors field observations and concrete participation in the planning process connected to the implementation of Solrød biogas plant, and from information provided by Lindgaard (2014) [37] and others:

Phase 1 consists of the initial pre-feasibility study, analysis of the biomass substrates/feedstock to be digested at the plant together with manure and a survey of potential owners of the plant, as well as location options (see Figure A). Phase 2 consists of parallel processes, the first being to elaborate the overall project report, conducted at the same time as contracts regarding e.g. substrates/ feedstock, manure and sale of energy, etc. Second, is to conduct the Municipal Plan Appendix along with proposals of the biogas plant design/concept, as well as preliminary bidding material. Third, is to elaborate the Local Plan and the Rural Zone Permit in parallel with both the EIA *and* the Project Approval connected to the municipal heat supply. The forth, and final task, will be to provide the Environmental Approval in parallel to Business Cases *and* the Final Bidding Material. Phase 3 will be the construction phase where the contract for constructing the plant is finalized and the actual construction of the facility is initiated.

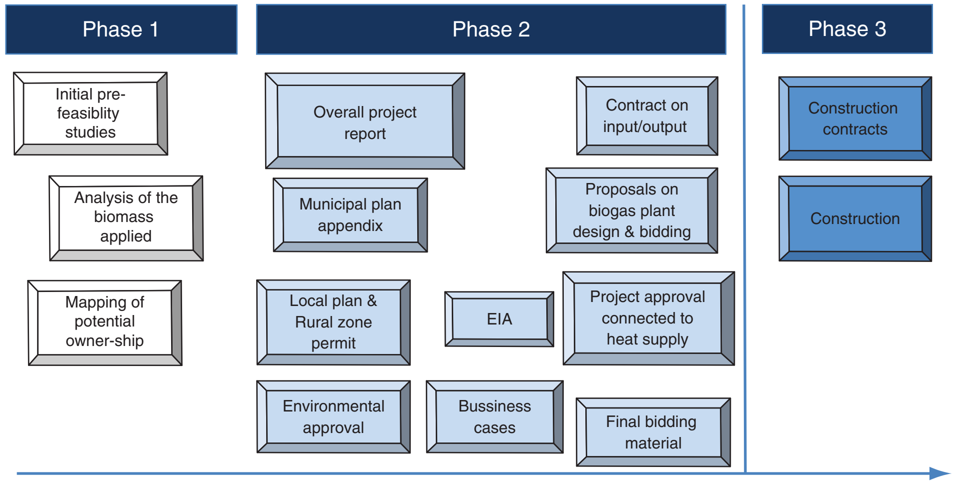

Figure A: From idea to project realization

After Phase 2 we suggest that project developers apply for municipal loan guarantees, as the project will be well prepared and the risks associated with the project minimized. To facilitate the biogas planning process, as described above, it would be beneficial if the national government could support Phase 1 and 2, due to the high costs connected with the tasks and analysis required in these phases. The total costs connected with the documentation needed in these two phases average 3.4 million DKK (453,000 Euro), of which the majority are connected to companies providing input to e.g. EIA, contracts, technical/juridical assistance. Thus, many stakeholders are reluctant to engage in biogas production, as the process is not only long, but also very costly [27]. We therefore suggest that national government grants are provided to support the work in this initial phase.

3.4. Slimming down the amount of documentation required

Slimming documentation could be achieved by setting a higher standard for the initial documents. Today, the EIA is often approved without including all the required and necessary data and information, which is compensated for in the later Environmental Approval [37]. The information needed in the Environmental Approval is almost identical to what is required in the EIA [28], [37]. Thus, a thorough EIA undertaken at the beginning of the process could make the Environmental Permit phase unnecessary, and hence lead to a faster approval process. This supports the above suggestion of conducting an overall project report in which all relevant data are available, and thus in general to be better prepared in the initial stage of a biogas project.

4. Heat planning (consumer/regulator/facilitator)

A municipal task in Denmark is to conduct heat planning. Municipal heat planning takes its point of departure in the Heat Supply Law [35], and in a planning system where heat plans are elaborated that began in the 1980's [38]. The planning system requires that municipalities should elaborate heat plans, with the purpose of limiting fuel utilization and substitute the oil consumption, as a consequence of the energy crises in the late 1970 [15].

Extension of the collective heat supply – not only in larger city areas but also in districts bordering city areas – can reduce GHG emissions, just as intensified use of renewables in the heat supply will, as is the case with biogas, solar heat, geothermal energy for collective or individual heat supply. Municipal heat planning should take its point of departure in enhanced physical planning, where the municipality, both in their municipal plans and in their local plans, can provide guidelines for an expansion of the collective heat supply (discussed in a later section) [38]. Another opportunity is to develop a market for biogas, substituting the use of fossil fuels currently being utilized [39]. Thus, municipal plans can describe how the municipality plans to reduce its GHG emissions by e.g. expanding the collective heat supply by means of, for example, biogas, and how the municipality will create a market for certain renewables and support renewables through other means including biogas.

4.1. Increase heat markets

Municipalities can actively increase the heat market targeting biogas by requiring a share of their heat supply to be produced by biogas, hence substituting the use of Ngas for heat production. This could be within municipal housing with individual Ngas boilers or in municipal buildings with gas-fired boilers, e.g. schools, sports facilities, etc. Another option is to expand the municipal heat marketHJ for biogas by requiring distribution of city gas based on biogas from manure-based plants [40]. This opportunity is not yet taken within Danish municipalities, but could eventually substitute the use of existing city gas provided by Ngas. The distribution of biogas supplied as city gas in Denmark only happens in the city of Aalborg and Copenhagen, where the biogas is produced from sludge generated on wastewater treatment plants. An enlargement of the heat market for renewables will allow municipalities to lower their CO_2 emissions and comply with GHG emission reduction targets as, for example, formulated in the Covenant of Mayors (see later) [41].

4.2. Identify alternative heat markets

Besides identifying heat markets within the sphere of the municipal energy consumption alternative heat markets can also be found including agricultural business, such as horticultures using heat during summer periods (night and early morning) as opposed to the traditional heat markets constituted by households during winter periods. Alternative markets could also include other types of manufacturing industries that would benefit from the supply of heat on a non-fluctuating annual basis, e.g. food manufacturing industries. This would benefit the economy of biogas CHP plants, as surplus heat during summer periods is most often cooled and thus lost. Alternative heat markets will therefore provide good opportunities for implementing biogas plants within the municipality with favorable plant profitability [42].

4.3. Mandatory use of biogas

Municipalities can actively support the biogas sector by requiring local Ngas CHP plants to utilize biogas from a nearby biogas plant as required by the Heat Supply Law. This will provide new opportunities for selling biogas and securing a certain income level when distributing the gas, hence making the investment in biogas technology less risky. Presently, many Ngas CHP plants are reluctant to accept biogas, in their mandatory transition to renewables, as they prefer cheaper types of green fuels such as wood chips, pellets and straw [43], [44]. The advantages of combusting biogas are however a cleaner fuel, access to a larger district heating network, and that the gas will be provided by the local community as opposed to imported wood brickets.

4.4. Realize biogas proposals

Municipalities can also actively elaborate project proposals for collective heat supply initiatives, hereunder the supply of biogas. Project proposals regarding, for example, the use of specific types of renewables, supply of energy to new industrial and residential areas, and interconnection (coupling) between energy systems, can thus be addressed [42]. Alternatively, the municipality can require energy supply companies to conduct project proposals, through the Heat Supply [35]. When a proposal is finalized and approved by the authorities the municipality can actually require the energy supply company to implement the project [35]. Project proposals emphasizing heat supply must in general meet the Danish political target of a CO_2 neutral energy supply in 2030, and it is therefore necessary to substitute the use of fossil fuels and to increase the resource efficiency [45].

4.5. Use biogas to substitute Ngas and oil

Municipalities should support biogas being primarily utilized for local CHP purposes with supply of district heating (DC) if a local heat market is available, as the economic and environmental benefits are highest compared to other types of biogas usages [46]. Otherwise, the energy could directly be distributed as non-upgraded biogas to industry and household, substituting oil & Ngas and Ngas used for city gas. If this is not an option other means of biogas distribution should be supported by the municipality (for example upgrading to the Ngas network and for transportation purposes) [42]. Such support could be achieved by municipalities providing help with calculations, pre-feasibility studies etc. of different biogas distribution options to select between.

5. Physical planning (facilitator)

The location of residential areas, office workplaces, institutions (schools, nursery homes etc.), industrial areas and technical facilities etc. are decided by municipalities in their city plans, which divides the city area into zones and separated physical areas, where each area is subject to a specific predefined planning framework or optic [47]. Beside the city plans, municipalities also point out areas for agriculture, raw materials extraction and for the implementation of wind turbines etc. in the more open land outside city areas, which also are subject to zoning and specific planning framework (Ibid.). Thus, we argue that physical planning that to a higher degree thinks across traditional zones and predefined landscape purposes etc. could support the implementation of biogas plants (and other renewables) in the municipal energy planning, and thus increase the use of RE. The importance of appropriate location of centralized biogas plants has recently been studied by Deep, et. al. 2015 [55].

5.1. Suggestive expansion of heat supply

The municipal city plan should establish an overview of existing and future residential and industrial areas seen in connection to its present heat supply, e.g. the physical existence of district heating and Ngas networks, etc. The biogas CHP plant, producing electricity, district heating and non-upgraded biogas, could thus be located in proximity to existing and near, future, residential and industrial areas, phasing out the use of Ngas in the existing heat supply by means of district heating.

The supply of energy could alternatively be provided by smaller local networks distributing non-upgraded biogas to cover industrial process heat demands (high temperature), or as district heating to household and industry (low temperature). Thus, a local network of low pressure gas and district heating pipes would distribute energy services to industry and households within the community. As the residential and industrial areas gradually expand new biogas plants could be established and the biogas networks could be integrated or coupled [42].

The distribution of biogas will thus develop as a suggestive expansion of the municipal heat supply, due to new residential and industrial areas being developed by means of the physical planning. A priority for such local gas networks should, however, be the supply of non-upgraded biogas to industry, as it often has a constant demand all year round [48]. This is the case in Ringkøbing-Skjern municipality, where the Dairy company Arla Foods, which produces milk powder, now will terminate their use of Ngas for process heat generation, and instead utilize non-upgraded biogas [49].

5.2. Energy distribution

The supply of energy from biogas plants can, as mentioned, be provided in local gas or district heating pipes, or supplied on the conventional Ngas or district heating network. In areas where a further expansion of the conventional district heating network is possible, it is beneficial to do so as the heat supplied from the biogas plant can be connected to a large distributing system. In this way, any surplus heat can be supplied on a network that reaches a larger area in the region. As opposed to areas, where a further expansion of the conventional district heating system is not an option, it is favorable to establish smaller networks for distribution of non-upgraded gas – preferably to industry – and district heating to both industry and households in the community [42]. The above planning should be undertaken in cooperation with neighboring municipalities in order to avoid competition of manure and biomass and to obtain synergies in heat planning.

6. Renewable Energy (RE) planning etc. (consumer/facilitator)

RE planning is important for supporting the implementation of renewables, and several elements connected to such planning can be utilized by municipalities to promote the implementation of RE in local communities. Besides municipal opportunities to support biogas we will, as mentioned earlier, also look at how national government can strengthen the framework conditions.

6.1. Climate accounts and targets; Covenant of Mayors

There are other options connected to climate, energy and the promotion of renewables within municipalities, for instance the Covenant of Mayors, which is an inter European association, or a convent, consisting of local and regional authorities [41]. The purpose of such collaboration is to promote the use of renewable energy and increase the energy efficiency. Participants are obliged – as a minimum – to live up to the EU target of 20% CO_2 reduction before 2020. EU recognizes that especially local authorities, municipalities, have a profound impact as far as minimizing the consequences of climate change. The Covenant of Mayors is thus a unique model for management of several local levels in combating climate change, due to its mobilization of local and regional stakeholders in complying to the overall EU target for CO_2 emission reductions, etc. [41].

Participants of the convent are obliged to elaborate CO_2 Accounts that is, baseline-accounts of their CO_2

emissions. One year after it is signing the covenant participants are required to provide a Sustainable Energy Plan (SEAP), which consists of a detailed plan of how to reach the specific, for example climate targets [41]. Every second year an Implementation Report must also be written to evaluate and survey the municipal activities, e.g. the implementation rate and impacts of the different ongoing activities. The board of the municipal must approve this Report [41].

Although the Covenant of Mayors has no legal implications for the municipal sphere, and there are no sanctions applied on municipalities not complying with their targets etc., it is beneficial for municipalities to join this convent. They will be included in a network of stakeholders throughout the EU that are motivated to combat climate change, and be provided with tools and knowledge of how to do so. The database Benchmark of Excellence will, for example, be available for participating municipalities, outlining best practices based on data from the convents members. The Sustainable Energy Plans will also be accessible from a database, showing which target other municipalities within the EU has, and how they will comply with them [41].

6.2. Strategic energy planning (SEP)

Strategic energy planning is a concept that allows municipalities to plan for their local energy supply to become a more flexible and more efficient energy supply system, so that the transition to renewable energy and energy savings can happen in the most energy efficient way for a given society. With this planning framework, the municipality, using knowledge about the existing energy system, including the current energy demand and future energy savings, and by surveys of available resources within the community should decide what the future energy supply should be. This should include the purpose of the Heat Supply Law, as well as local policy objectives on energy within municipalities [50].

Municipalities will prepare the first generation of strategic energy planning simultaneously, and in line with the local plans, achieve the expected synergies through inter-municipal cooperation and coordination with other municipal planning activities. In order to achieve the necessary flexibility and energy efficiency, the plan will not only affect the collective heat planning, but also other elements of the energy chain as cooling, energy conservation and dissemination of individual renewable energy technologies [50].

We believe that municipalities can use strategic energy planning to integrate renewables, including biogas, in their energy supply in short, middle and long terms. Setting up goals for its share of the energy supply and by which conversion methods SEP should be integrated in the energy system. The strategic energy planning can for example, in the short term, focus on the EU/SEAP initiated targets for 20% CO_2 reduction within 2020, and in the middle term achieve the targets of a fossil free power and heat supply in Denmark by 2035. The long term could be to live up to the targets of a fossil free energy supply by 2050, which includes the transportation sector.

Thus, SEP could for example indicate that biogas in the initial phase primarily should be used for biogas CHP – district heating to households, low temperature process heat industry, gas to industry and for city gas – without an expensive upgrading to Ngas standards. Secondly, to push the energy and transport system to evolve the biogas should subsequently be used for transportation and Ngas purposes, emphasized below. At this later stage, the costs connected with upgrading biogas would eventually be reduced due to new technological innovations.

6.3. Vehicles fleet

Biogas for transportation purposes is in its very infancy in Denmark, and only a handful of service stations provide for gas vehicles using Ngas, but more will be established in 2015/16 [17]. Danish municipalities can play an important role in creating a market for biogas for transportation. Thus, a large municipality or company vehicle fleet could initiate a development of biogas for transportation, e.g. the municipality of Copenhagen or a large taxi company. For example, Sweden has busses and trucks that are operated on biogas derived from biogas plants, as mentioned in the introduction [12]. To motivate municipalities to engage in this, they could look to the climate related benefits of using gas for transportation instead of diesel or petrol. Municipalities should therefore be able to calculate the carbon benefits from the use of biogas into their carbon accounts.

6.4. Biogas feasibility

Municipalities can also assist local stakeholders by providing knowledge regarding the economies of implementing a biogas plant. They can thus provide assistance regarding calculations in and pre-feasibility analysis of the value of biogas in different supplyscenarios using their own SEP knowledge. They could also provide assistance by supporting and facilitating negotiations when doing supply contracts, etc.

6.5. Financial support

It would also support the biogas sector if municipalities could disseminate knowledge regarding financial support provided by national government/municipal funds e.g., discussed below:

Grants for planning the implementation of biogas plants should be available. This is already the case for windmills, where financial support from the national government is provided in the initial phase of the planning for erection of windmills in local communities. Grants could also be available for supporting the distribution of small local biogas networks, as in e.g. Ringkøbing-Skjern municipality [51], which could support the build-up of a decentralized biogas infrastructure, making biogas projects more economically viable due to an enlargement of local markets.

Provide a public loan guaranty (e.g. 1–1.5% interest rate plus the interest rate of the National Bank), for investments in biogas plants are important [52]. This will lower the production costs of biogas and make the plants less dependent on substrates, etc. It is pivotal for the biogas development that a municipal loan guarantees (low interest rate loan) can be obtained, if the Danish national government cannot provide such grants. If the Danish government cannot provide the grants and loan mentioned above, we suggest that municipal grants could be provided where possible.

6.6. Map biomass potentials

Another opportunity for municipalities to support the biogas sector is to identify or map the available biomass potentials that could be supplied to biogas plants consequently boosting gas production. Available livestock manure, deep litter, mink and poultry waste, residual straw, biomass from natural conservation etc. Municipal support could also include the potentials for growing energy crops, and how source separated household waste can be supplied to the plants. This will assist the sector in applying feasibility studies concerning which type and size of plants to implement, and the potential gas yield etc. Such work could be coordinated with neighboring municipalities to avoid competition or double counting of resources [29].

7. Summary of all support opportunities

Table A: Summary of the municipal support opportunities for biogas

Municipalities	*Consumer*	*Regulator*	*Facilitator*
Regulation & Supervision			***Speed up the authority work process*** ***New biogas approval process and flow (could be provided by the Danish national government)***
			Slimming down the documentation required
Heat Planning	***Increase the local heat market***	***Increase distribution options***	***Support pre-feasibility studies***
		Require projects to be realized	***Identify alternative heat markets***
Physical Planning			***Suggestive expansion of the heat supply***
RE Planning	***Increase the local market for renewable energy***		***Adopt Covenant of Mayors & Strategic Energy Planning (SEP)***
			Conduct biogas feasibility analysis
			Dissemination of options for financial support (preferably provided by the Danish government, but alternatively by municipalities where economic possible)
			Continue public loan guarantees (could be provided by national government
			Mapping local biomass resources (boosters)

8. Discussion and conclusion

Municipalities can play a vital role in supporting the biogas sector, through their role as facilitators, consumers and regulators; the first of these having the highest impacts. The municipalities' role as biogas *facilitator* is very important, and the support opportunities identified, should therefore be applied where possible. Within Regulation and Heat Planning we suggest speeding up the biogas process and slimming down the documentation required. Within Heat Planning we suggest supporting pre-feasibility studies and identify alternative heat markets. In Physical Planning a suggestive expansion of the heat supply is suggested, and within Renewable Energy Planning we recommend the adoption of the Covenant of Mayors and SEP, and to assist stakeholders with biogas feasibility studies and mapping local biomass boosters, etc.

The opportunity analysis shows that local governments (municipalities) in Denmark can support biogas in various ways. It will, however, hardly be realistic to apply all the suggestions mentioned above in each municipality. Support for biogas is context dependent, so each community will have to select between the suggestions provided after having conducted a status of the biogas situation locally. As illustrated, the highest impact on the biogas sector is identified within municipalities, through their role as facilitators, then as consumers and finally as regulators. This indicates that the municipal role as facilitator is extremely important in order to support this sector and that as many of the suggestions provided above should be applied where possible.

We argue that the work with biogas in connection to the strategic energy planning (SEP) is especially important, as is can be used to set targets for biogas within municipalities in the short, middle and long run, and thus include some of the suggestions on how to apply more energy from biogas in the municipal energy supply, e.g. city gas, vehicle fleet on biogas, etc. The focus on inter-municipal work in the SEP is also very important, as the catchment area for biomass (manure and gas boosters) and the distribution of energy, can include a large area and thus more than one single municipality. Dialogue between stakeholders is therefore fundamental.

Biogas technology provides a flexible source of energy that can be integrated in the energy supply systems of local communities in various ways; thus biogas can be adapted to many different contexts and assist in the transition of the energy supply. Biogas can be upgraded to Ngas and Stored in the well-distributed Ngas networks, and e.g. be utilized as a back-up and fast start-up fuel on decentralized CHP plants, when wind turbines do not provide base-load electricity in a future Danish energy system, based on 100% renewable energy [45]. Biogas is perceived as an important transition technology that can be employed to meet some of the energy supply challenges that Denmark, and many other countries are facing. Biogas is connected to not only the energy sector but also to the agricultural sector, and these sectors therefore constitute important infrastructure that support the development of the technology, and must be nursed in the right direction as suggested here.

Deployment of the biogas at the local level can constitute an engine that provides local governments (municipalities) with the supply of renewable energy that adds value and generates bio-economic solutions related to production and consumption of energy, and agricultural activities. Environmental benefits at the local level, such as improved air quality from distribution of manure as fertilizer, enhanced soil quality and prevention of nitrogen leakages etc. are also co-benefits, which can improve local citizens' everyday lives, as well as natural ecosystems [11].

Biogas can thus act as an urban-rural link in which organic waste streams are recycled back to farm land as nutrients for agricultural crops, and promote the development of more sustainable agricultural practices, hereunder the expansion of organic farming. Biogas can furthermore reduce soil contamination by hygenization and sterilization and provide farmers with a better quality soil in which soil depletion is avoided. To promote these benefits we suggest that local governments, besides the suggestions already made, focus on facilitating the supply of biomass substrates with high content of nitrogen, which could create additional benefits for farmers in terms of crop yields and saved expenses to artificial fertilizers, e.g. grasses like clover grass and ray grass.

Applying more substrates (gas boosters) than the allowed amount by 2018 (will be limited to 12% from now 25%) [53], will need to be revised for *some* gas boosters, as the nitrogen level of the digestate (fertilizer), and thus the gas yield, will be too poor to favor a continued dissemination of the biogas technology in Denmark. Grasses containing high nitrogen levels can for example be harvested from extensively farmed soil, from areas dedicated natural conservation and as cover crops. In this way, valuable farm land utilized for food and fodder production will not be included in the growing of energy crops, as seen in other European countries, e.g. in Germany [8], [54]. Here large land areas are devoted to the production of, for example, beet and maize for biogas production, jeopardizing the sustainability of biogas feedstock.

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