Future Pathways for Deploying Agricultural Based Biogas Plants in Denmark and Japan: A Comparative Analysis

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Abstract— *This article analyses the Japanese and Danish biogas sector as a multiple case study with the purpose of enhancing biogas deployment within the two countries, which have almost the same numbers of biogas plants implemented within the agricultural sector. The two cases are analyzed in respect to their: 'Production and use of biogas for energy services', 'Utilization of digestate', 'Framework conditions supporting the biogas sector' and finally, 'Current trends in the biogas development'. To support the analysis two biogas plants in Japan and three in Denmark were visited respectively. It is, among others, found that support by various stakeholders are needed to e.g. improve the utilization and distribution of digestate in Japan, and that requirement of higher energy efficiency on new biogas plants would be favorable, as for example Combined Heat and Power (CHP) production. At the same time a more systematic mapping of markets for export of energy are needed due to limited district heating (DH). In Denmark, new regulation supporting e.g. export of raw biogas is needed, and more emphasis and support to organic biogas plants should be considered to expand both biogas dissemination and organic agriculture.*

Keywords— **Biogas, Denmark, Japan, framework conditions, dairy cattle, pigs, manure.**

1. INTRODUCTION

From animal manure (a mix of slurry and solid animal waste), and other organic feedstocks, it is possible to produce biogas, which is a side-product from the respiration of microorganisms' decomposition of different types of organic materials. In the production of biogas, it is thus common to utilize manure from livestock, sludge from waste water treatment, residues from agriculture and industrial biomass, and waste from for example the food and agro-industry [1]. It is the type of organic materials being decomposed that determines the amount of methane that is produced, i.e. fatty or greasy organic materials lead to a high gas production, whereas materials primarily containing carbohydrates, like glucose and other simple sugars - as well as high-molecular like cellulose and hemicelluloses - lead to a lower gas yield. The combustible part of the biogas consists primarily of methane and hydrogen. It is an odorless and colorless gas with a boiling point of -162 degrees C, and it burns with a blue flame. The gas has a density of 0.75 kg/m3 at normal pressure and temperature, and an upper calorific value of 39.8 MJ/m3, corresponding to a potential energy production of up to 11 kWh per m3 biogas [1].

Denmark and Japan are two developed countries with a long tradition of working with renewable energy and energy efficiency. Both countries have highly advanced industrial businesses and corporations, as well as an agricultural sector based on various agro-products, hereunder livestock farming. The organic waste materials from livestock husbandry have been utilized for biogas production in Denmark and Japan for many years; in Japan, primarily from dairy cattle farms and secondly from pig farms, and in Denmark the opposite [2], [3]. The primary feedstock for producing biogas today in a Danish context - and to a minor extension in the Japanese - is animal manure. Other fractions like industrial organic waste, sludge, agricultural crop residues and household waste, etc. are also utilized to increase the gas yield and to apply waste management [2], [3].

The total number of agricultural based biogas plants in Japan is currently about 70-80 [4], [5], where the majority are applied in Hokkaido, then Honshu and finally Kyushu [6]. The biogas plant concept is mainly Farm scale plants, with some plants also being larger Centralized biogas plants (see description of the two concepts below). The electrical energy produced is in some cases sold and transmitted on the power grid, which has been promoted by a Japanese feed-in-tariff (FIT) scheme. The generate heat is mostly used for internal process heat purposes, and only in rare cases exported for other means of usage. In the Japanese context, the digestate (digested manure) are applied as fertilizer on farmland in areas where arable land is available. In other areas, de-watering takes place to reduce volume, and the liquids treated in waste water treatment plants (WWTPs) [3].

In Denmark and Japan two kinds of biogas concepts are thus implemented; large scale Centralized biogas plants and Farm biogas plants. In the Danish context, these plants add up to a total number of 79 plants, hereof 30 being Centralized plants. The latter receive animal manure from several participating farmers, as well as organic waste from e.g. the food and beverage industry, oil residues from the fish industry and organic fractions

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from commerce, etc. Some Centralized plants have also started adding different types of agricultural residues (straw, grass) and energy crops (beet, maize, etc.) to increase the gas yield [2]. The Combined Heat and Power (CHP) produced is mostly distributed as heat in a local district heating network or sold and distributed on a larger system within the region. The electricity is transmitted on the power grid. On Farm biogas plants the feedstock normally also consists of a mix of animal manure and organic materials e.g. grass, beet, deep litter, maize etc., but from a single or neighboring farms only. The heat is utilized for internal process heat and the electricity transmitted on the power grid [2]. All digestate are utilized as fertilizer in Denmark.

2. PROBLEM AREA

The biogas situation in Japan and Denmark has both differences and similarities; the two countries have almost the same amount of agricultural biogas plants implemented, and the climatic conditions of Denmark correspond to especially the Hokkaido area in the Northern part of Japan, where the implementation of biogas plants is the highest due to a large density of livestock [7]. Moreover, the timeframe concerning when both Denmark and Japan started to adapt to the biogas technology are also quite similar. In Japan, however, the deployment of Centralized plants is still limited and efficient heat utilization from biogas scares. Some livestock farmers with large farmland areas excessively apply the digestate as fertilizer, while others, with a limited farmland area, have difficulty finding crop farmers who will utilize their digestate.

For the case of Denmark e.g. better framework conditions for utilizing the generated biogas is necessary to increase the local heat markets, just as new types of biogas concepts should be promoted much more. For both countries apply, that the pace by which the biogas technology is being implemented could be significantly improved. This article will therefore explore new development opportunities for the biogas technology within both countries and discuss how to promote the technology further, comparing and learning from the two cases.

3. METHODOLOGY

The methodological approach in this paper is to conduct a multiple case study analysis [8], emphasizing on two cases, here Japan and Denmark, as far as new expansion opportunities within the biogas sector. A comparative analysis of biogas between Japan and Denmark is not available within the existing literature, and there is thus a need to analyze the two contexts and disseminate the findings. Comparison of the biogas sector between two countries have, however, been done before, by for example [9], looking into the waste management practices in Ghana versus Canada, hereunder the city of Ontario.

In this article, we have chosen to focus on Denmark and Japan in our investigation, as the number of plants and climate in Japan (selected area) are quite similar to the Danish. The main focus is therefore Danish and Japanese - with special emphasis on the Hokkaido area where possible - biogas technology and production, connected specifically to livestock farming. Thus, biogas within other sectors as e.g. waste water treatment and landfill gas is not emphasized. Comparison will be applied on the following elements, constituting the biogas sector within the two countries;

- Use of feedstock in the biogas process
- Production and use of biogas for energy services
- Utilization of digestate
- Framework conditions supporting the biogas sector
- Current trend in the biogas development

The data utilized in this paper derive from various sources, as for example literature studies of e.g. biogas and agricultural reports, journal articles and legislative documents providing overview of governmental legislation within the biogas sector. Moreover, empirical data has been collected through interviews and field studies on three Danish biogas plants and two Japanese plants. The empirical approach was selected with the purpose of identifying hands-on current trends within the biogas sector. The following Danish biogas plants were visited as a part of this study in August 2016 and the managers of the plants interviewed:

- ‘Nature Energy’ Centralized biogas plant (upgrading to Ngas)
- ‘Linkogas’ Centralized biogas plant (CHP & upgrading to Ngas)
- ‘Ribe Biogas’ Centralized biogas plant (CHP & future upgrading to Ngas)

In the Japanese context, the following two plants were visited on April 2016, and plant managers interviewed, to provide empirical data for this article:

- ‘Shikaoi Biogas’ Centralized biogas plant (Power production & Use of excess heat)
- ‘Shihoro Biogas’ Farm Biogas plants (Power production & Use of excess heat)

We will now proceed with a description of the Danish and Japanese biogas sectors in the following parts, and in a discussion section compare the two cases, and finally, conclude on how to expand the biogas sector and thus development opportunities for the biogas technology within the two countries, hereunder suggest on new framework conditions.

4. BIOGAS IN DENMARK

4.1 Histrotical development

The Danish biogas sector was established in the political context of the late 1970’ties energy crisis. The objective of supporting implementation of the biogas technology was to supply renewable energy and thereby to increase the energy security based on indigenous resources. Focus on the environmental benefits of integrating biogas production and agriculture were scarce. From there on the development of the Danish biogas sector has been widely influenced by Danish public policy. This influence can be seen directly through the governmental funding of development and demonstration programs and indirectly through the framework conditions that was formulated in policy programs, energy plans and environmental protection legislation, etc. [10]. Thus, the aims and objectives of the programs have been shaped by changing policy regimes, as follows:

In the 1970'ties focus was on energy security following the energy crisis focusing on Farm biogas plants. But already in the mid 1980'ties the emphasis shifted to small scale Centralized biogas plants, the first one being implemented in Vester Hjermitslev in 1984 with focus on reducing nutrient leakage from the agriculture. In the late 1990'ties and the 2000'ties emphasis shifted to large scale Centralized biogas plants, and focused on climate policy, agricultural policy and environmental protection all together. Public policies have thus been vital for the development of the Danish biogas sector, not only in terms of funding development programs, but also when it comes to shaping the direction of technological choices. Policies have also shaped development of biogas as solutions to environmental problems related to e.g. leakage of nutrients to the aquatics', to the production of renewable energy or to combining these policy objectives [10]. Knowing how important public policies historically have been for the biogas sector in Denmark, it is therefore vital to continue this support to facilitate a further dissemination of biogas technology.

4.2 Number of plants, size and organization

There are currently 30 Centralized biogas CHP plans in Denmark that receive livestock manure from several participating farmers, primarily from pig and dairy cow farms, as well as from other types of feedstock' e.g. mink and poultry manure. Denmark also host approx. 49 Farm biogas plants, which are located at a single farm, and are most often based on feedstock from a large stock of dairy cows or slaughter pigs. Apart from this approximately 60 biogas plants are operated in connection with waste water treatment plants and digest sludge from the cleaning process. Moreover, 27 plants utilize landfill gas, and finally six industrial plants are established digesting sludge from e.g. medical and food manufacturing industries [2], [11]. Centralized biogas plants are most often jointly owned by farmers, or farmers and e.g. the local municipality. The plants are then established with low interest rate municipal loan guaranties, due to their contribution to the municipal heat supply. Lately, some plants have been established as a joint ownership between farmers and natural gas companies, allowing sale and distribution of upgraded biogas to the natural gas (Ngas) network [12]-[14]. Currently, the energy production from biogas plants in Denmark - including plants connected to WWTP's, etc. - account for 9 PJ of a total energy consumption of 700 PJ. The full biogas potential is estimated to 40 PJ [50].

4.3 Use of resources and energy etc.

4.3.1 Feedstock

Danish Centralized biogas plants digest agricultural residues such, like e.g. rape oil and seed, soybean, corn residues, wheat straw, deep litter, fruit and vegetables residues, as well as fish wastes, different residues from the food industries e.g. flotation grease, and intestinal contents from slaughterhouses. Again, other plants also digest organic source separated food waste from kitchens and canteens, as for example from the city of Copenhagen. Within recent years some Centralized biogas plants have also started to add different types of agricultural residues (straw, grass) and energy crops (beet, maize) to increase gas yield. On Farm biogas plants, the feedstock can also include a mix of organic materials (e.g. grass, beet and maize), deep litter and animal manure, but usually comes from the biogas farm it selves or supplied by neighboring farms [15]. Larges unused biomass feedstock are available for biogas in Denmark e.g. deep litter, straw, clover grass from crop rotation, organic waste from commerce & household, blue biomass (seaweed), which could supplement the scarce organic industrial waste and the use of energy crops [2].

4.3.2 Enery usage

Existing Centralized biogas plants typically distribute heat to a local market of heat consumers by means of district heating (DH). The size of the market can vary greatly from a few hundred customers to several thousand, dependent on whether the district heating system is a smaller local network, or connected to a large network in the region. A challenge here is that biogas CHP plants, connected to smaller local DH networks, cannot distribute all the generated heat produced during summer periods, as the demand for primarily space-heating decrease. Connection to a larger DH network is therefore favorable, as it expands the opportunities to reach a larger heat market.

The biogas has thus historically been utilized almost exclusively for CHP production in Denmark [11], but several new plants are now designed to distribute gas on the well-distributed Danish natural gas (Ngas) network [16]. 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 Ngas [15], [17]. Hereafter, it is injected into and distributed via the Ngas network with a total price of approx. 1 DKK/m3 Ngas (0.133 Euro Cent) [13]. On Farm biogas plants the biogas is also here converted in a motor/generator for power and heat production (CHP), but with limited heat utilization due to the relatively limited heat demand within the farms. The heat will most often just cover internal heat demands in e.g. pig stables and farmhouse, and any surplus heat would normally be wasted [10]. On a few newer Farm biogas plants, the gas yield is so high that upgrading to Ngas has been applied and thus distributed on the Ngas network.

4.3.3 Digestate

In Denmark, the digestate are distributed on farmland as valuable fertilizer and farmers are in generally very interested in this type of nutrient, as the crop yield increase compared to artificial fertilizer. The annual production of livestock manure in Denmark accounts for 30 mill. tonnes, but only six per cent of this amount is digested in biogas plants. But when digested, together with various other types of feedstock, it becomes a liquid easy to distribute on farmland by drag hoses. Nutrients in the fertilizer become more directly assessable for the crops, as the chemical form shifts to ammonium. This means that the risk of nutrient pollution to rivers, lakes and ground water reservoirs are reduced. Also, odors connected with distribution of manure on the fields decrease by as much as 30 % [1]. As the digested manure receives a declaration of its content of nitrogen, phosphorous and potassium, it enhances the opportunities for controlling and regulating the distribution of nutrients on farmland even further.

The price of transporting manure between farms and biogas plant are however relatively high. It is not unusual that up to 30-35 % of the operational costs of a Centralized biogas the plant is utilized on transportation [1]. On Linkogas, for example, 30 trucks arrive daily with manure from participating farmers, and with 40 tonnes manure per truck, it adds up to 370,000 m3 feedstock being transported annually [12].

4.4 Existing framework conditions & policies

Danish biogas plants currently contribute 4.2 PJ or 0.5 % to the national energy consumption, which totals 750 PJ [18]. As mentioned, 60 % of this energy is produced at biogas plants, and the remaining on waste water treatment plants and landfill sites, etc. The estimated total available manure (manure and available organic waste, etc.), which could be treated in Danish biogas plants, constitutes a potential of approximately 40 PJ of energy. The ‘Energy Agreement’, launched in 2008, state that by 2025 30 % of the Danish manure should be digested, amounting to 12 PJ [19]. In 2009, the Danish government then launched its ‘Green Growth Strategy’, which stress that by 2020 50 % of the manure should be digested, providing 20 PJ of energy [20]. The 50 % target in 2020 will e.g. provide Green House Gas (GHG) emission reductions corresponding to approximately 580,000 tonnes of CO_2 equivalents annually [11].

The Danish Government supports the implementation of biogas technology by economic support to electricity production, and a 30 % construction grant. The FIT is currently (2016) set to 123 DKK/GWh (16.4 Euro), and consists of a three-tariff system where two are permanent and one indexed and flexible following the Ngas prices. Support to upgrading of biogas to Ngas standard is set to 122.6 DKK/GJ (16.35 Euro) - for higher burning value - and 110.5 DKK/GJ (14.73 Euro) for lower burning value [21]. The support to biogas upgrading relies on a three tariff-system. Economic support is also provided to industry that own and operate a biogas plant and utilize the energy for internal process purposes, e.g. pharmaceutical industries. Biogas for transport is also included in the government support scheme, but requires that no energy crops are added in the biogas plants producing the biogas for transportation purposes [21].

Regarding the latter, the use of energy crops is also regulated in the Danish context, now allowing the use of up to 25 % - measured by weight - of the feedstock being energy crops (maize, beet etc.). In 2020 this will be reduced to 12 %. A clear political statement indicating that the biogas sector should utilize other types of feedstock in the future to increase the gas yield [22]. As of now no support are provided for schemes where biogas plants supply raw biogas directly to other industries, substituting the use of e.g. Ngas for internal heat production within industrial/agro manufactures. Such incentives would benefit the biogas sector as new close-by markets for biogas will occur, for instance supply of raw biogas to local agro-industries.

4.5 Development trends

The Danish biogas sector has historically been constituted by the agricultural sector, but the economic crisis within this sector has restricted funding opportunities of new biogas plants in recent years. Agricultural biogas plants are primarily deployed as manure-based plants, with limited amount (per weight) of organic industrial waste boosting the gas yield. The market for energy has primarily been composed by local CHP plants supplying DH within a local community. The situation is however shifting relatively fast. Like in Sweden and Germany, new actors emerge on the biogas scene, and Ngas companies now play a role within the biogas sector. Thus, biogas will increasingly be upgraded for distribution on the Ngas network, which also clearly were the picture on the biogas plants visited [12]-[14]. Organic household waste and alternative biomass (straw, deep litter, clover grass, etc.) will most likely substitute a large fraction of the industrial waste and energy crops in the future. The biogas sector is indicating that they are working in this direction [14]. A new development within the sector is also the implementation of new biogas concepts; Organic Farm plants, where the feedstock originates from e.g. organic dairy farms. On Centralized plants this concept is implemented as a side-line to conventional biogas plant [12].

Thus, the Danish biogas sector evolves and become more like the biogas sector in Sweden and Germany, as far as generating upgraded gas, and like the latter as far as deploying organic biogas plants. A completely transition away from the production of CHP (like on small biogas plants in Germany due to historically high FIT, which made efficient use of heat unnecessarily), is however not considered likely. If a local market for heat is available it is more economically feasible to establish the biogas plant as a CHP plant, and distribute DH to a local community [23], or to distribute raw biogas to nearby industries with a heat demand. However, plants located in areas with a saturated or non-existing heat markets are very likely to upgrade the biogas and inject into the Ngas network.

5. BIOGAS IN JAPAN

5.1 Historical development

In Japan, the implementation of the biogas technology began already in small scale in 1940'ies originating from China and India [24], and continued up through the 1950'ies and 1960'ies promoted by Japanese policies, but failed primarily due to insufficient gas production and the introduction of cheap petroleum. The biogas development speeded up again with the energy crisis in the 1970'ties and 1980ties, due to high fossil fuel prices, and thus provided a cheap energy substitute utilizing indigenous resources. During this period, several small-scale Farm biogas plants were implemented, as well as governmental supported demonstration plants, but the technology did not receive much attention in general [25].

The pace of biogas dissemination, however, slowed down again as the oil prices fell, and not until the 1990'ties - where Japan applied a 'recycle-oriented society' - the technology came into focus again with governmental programs supporting e.g. technology development [25] and waste management from agriculture. Policies on 'manure management', 'food waste' and 'biomass' in general however changed the situation [26]. More public attention was thus given to biogas and new plants were consequently being implemented, but the pace of technology implementation faded out in the middle of 2000. A stagnation period for biogas deployment were seen, despite the e.g. Biomass Town Plan initiatives promoting biogas within Japanese municipalities [27]. After 2012, and due to better policies related to sale of power to the grid (FIT), the sector has now enlarged, but the pace of biogas deployment could be significantly improved.

5.2 Number of plants, size and organization

There are currently between 70-80 biogas plants connected specifically to the agricultural sector in Japan digesting animal manure and other types of organic feedstock, and around 40 of these plants are located in Hokkaido [4], [5], [28]. Besides this, there are implemented 120 additional biogas plants that digest mainly organic waste from food industry, landfill biogas facilities and plants that receive Municipal Solid Waste (MSW) [5]. Moreover, numerous biogas plants, connected to waste water treatment, are established. The total number of WWTPs has now increased to 1,900 [29], and today there are more than 300 biogas plants connected to these facilities [4].

Most of the agricultural based biogas plants are established as Farm biogas plants, but the precise number of both the Farm biogas plants and Centralized plants is unknown, due to lack of appropriate statistics data and the current construction taking place. Farm biogas plants are mostly owned by individual farmers, and Centralized plants mostly owned and established as governmental demonstration and research programs connected to universities [30], or by municipalities as waste treatment facilities, e.g. as part of the Japanese Biomass Town Plan (for more detail see Section 5.5.) However, some agricultural cooperatives have also established Farm biogas plants - on behalf of farmers not being economically capable of investing in such technology themselves - and then lend the facilities to farmers [31].

The energy contribution from Japanese biogas plants are not specifically extracted, but included in the figures for total renewable energy production accounting for 4,7 % of the energy supply. Energy from biogas is however expected to increase in the future, as better framework conditions most likely will be established for agricultural based biogas [49], [50].

5.3 Use of resources and energy etc.

5.3.1 Feedstock

On some of the Japanese Farm biogas plants the feedstock is solely cow manure or secondly pig manure and e.g. bedding material like straw, and on others a mix of feedstock like e.g. manure, MSW, excreta sludge, rice straw and husk, and different food wastes [6], [25], [32]. Some local municipalities have constructed Centralized biogas plants, with the purpose of applying feedstock like e.g. food waste from kitchens and canteens and residues from the food industries, in order to save waste treatment costs and to reduce the amount of final waste to landfill and incinerate [33]. In the Hokkaido area Farm biogas plants primarily digest cow manure, as the density of dairy cattle are quite high - more than half of the dairy cattle in Japan is home to Hokkaido [7] - and on some plants also add supplementary organic feedstock like mentioned above [32]. In the Japanese context, large amount of manure is potentially available for biogas production, which could be assessable if new distribution systems for digestate were to be developed [30].

5.3.2 Enery usage

In the Japanese context electricity is sometimes sold and transmitted on the power grid [30], and together with the generated heat also utilized for internal process purposes within the farm. In other cases, the biogas is simply burned in a gas boiler (heat-only) and the generated heat utilized internally, for instance on pig farms with a high demand for heat in stables and on dairy farms with a heat demand in processing raw milk.

Only a few larger plants distribute excess heat outside the biogas facility, and thus utilize some of the excess heat. In general, however, the biogas plants tend to have a large surplus of waste-heat [6]. With very limited DH systems throughout Japan efficient use of excess heat is a challenge [28]. Many Farm plants in Japan are however relatively small with a low heat production and the farmers are therefore capable of utilizing the heat internally, especially in Hokkaido where the climate is cold. Still, waste heat can be seen on Farm plants, especially on larger once. Heat distribution from a Centralized biogas plant in Shikaoi in Hokkaido is for example applied - visited as part of collecting data for this paper - which distributes excess heat of 70 degrees C. to a nearby greenhouse that grows mango and to fish tanks for cultivating sturgeon [33]. Thus, on some of the newer Centralized biogas plants the issues of heat efficiency and utilization is also considered when designing the plant.

5.3.3 Digestate

The Japanese introduction of regulation on animal manure in 2004 drastically changed livestock farmers' manure treatment. Currently, about 90 % of the total amount of manure in Japan is composted and utilized as fertilizer, and the remaining manure treated through a purification and incineration process [34]. The latter option costs higher for individual livestock farmers compared to composting manure [34]. In case of digestate, it is normally utilized as fertilizer where farmland is available, primarily in Northern Japan (Hokkaido) and in the Northeast (Tohoku), and in the paddy fields in South of Japan in the area of Kyushu [35]. On most biogas plants in Japan the digested manure is utilized as soil fertilizer, but the owners of some plants with limited access to farmland need to de-water the digestate, then composting it and finally apply waste water treatment of the liquid part, removing nitrogen and phosphorus for environmental concerns [25].

Utilization of digestate as soil fertilizer is a first priority today when farmers start up a biogas project, but this can also obstruct the construction of new biogas plants in an area with shortage of farmland. In Hokkaido, some farmers have recently begun to utilize the de-watered digestate as bedding materials for dairy cows in order to come up with other means of usage. It is de-watered and heated for a week using excess heat from the biogas plant, and then used within farm stables or sold to other farmers in the area as bedding materials [28].

One of the challenges with manure in Japan is also connected to the import of animal feed (roughage), which imply that the size of farmland not always correspond to the number of livestock and thus make the spreading of digestate problematic [36]. The yearly production of livestock manure in Japan is estimated to 89 mill. tonnes annually, from where it is assumed that a theoretical recovery - corresponding to 1.6 billion m3 biogas - can be produced [25]. In Hokkaido livestock manure from dairy cattle primarily is estimated to 20 mill. tonnes annually [28].

5.4 Existing framework conditions & policies

Since the March 2011 earthquake and the Fukushima nuclear plant disaster, the Japanese government is promoting renewable energy, which is expected to provide 10 % of the country's primary energy supply by 2020, according to the [37]. When the government's Strategic Energy Plan was updated in 2014, it advocated a further promotion of renewable energy [38].

Currently, different types of subsidies and grants are provided in order to promote biogas utilization by Ministry of Agriculture, Forestry and Fisheries (MAFF) and Ministry of Economy, Trade and Industry (METI) respectively. Also, public banks such as Development Bank of Japan (DBJ), Agriculture Forestry and Fisheries Finance Corporation (AFFFC), and Japan Finance Corporation for Small and Medium Enterprise (JASME) finance in biomass projects to encourage the investment on biomass projects [39]. The most effective public support to the biogas sector in Japan has, however, been the introduction of FIT in 2012 authorized by Agency for Natural Resources and Energy [40].

The FIT was revised in 2015 and now ensures the purchase price for the biomass-generated electricity of 39 JPY/kWh (0.34 Euro) (before tax), which is guaranteed for a period of 20 years. In addition, there are various options available to get subsidized for the plant construction. For instance, the subsidy from MAFF can cover maximum 50 % of construction costs [41].

Previously (2003), the Japanese government had launched a Renewable Portfolio Standard, "RPS", which allowed the biogas plants to sell electricity to the grid, but the purchase price was quite low (7~8 JPY/kWh (0.06 ~ 0.08 euro)). Due to high cost of construction and operation of biogas plants - together with this low electricity purchase price - many plants in Japan could not obtain profitability and failed to continue their operating [42], [43].

Thus, in 2009 the government reported the necessity of a FIT in the context of increasing renewable energy needs, and in 2012 the "FIT System for Renewable Energy" was finally enacted and revised in 2015. Although it has supported and steadily fostered renewable energy development in Japan, the potential of biogas energy has far from been fully exploited. Literature [44] suggest that biogas plants still account for only 0.04 % of the total electricity production, from plants established *after* the 2012 FIT enactment. This suggests that much more potentials and focus should be given to the biogas sector.

5.5 Development trends

Since 2004, where the before mentioned Biomass Town Plan had been launched through a cooperation among seven ministries, Japanese municipalities have started elaborating their own project proposals regarding domestic biomass usage, such as wood chips and pellets, wasted vegetable oils for biodiesel, kitchen waste, sludge and animal manure. In 2012 the policy had been updated and re-named "Biomass Industrial Town Plan" [45]. Currently, there are 34 municipalities/regions selected by the ministries, and among them four projects have declared that the main feedstock will be animal manure for biogas production. These four projects are all in Hokkaido: Tokachi region (including Shikaoi town and Shihoro town), Betsukai town, Kushiro city and Okoppe town. The projects in Tokachi and Betsukai were selected in 2013 and two others in 2014, meaning that these projects just have started up [45].

With the introduction of the FIT, two large-scale Centralized biogas plants in Shikaoi town and Betsukai started operating from April 2016 and July 2016 respectively. The new plant in Betsukai, utilize dairy cattle manure from 94 participating farmers, resulting in a total of 280 tonnes of manure including straws and bedding materials daily, and generates 12,000 m3 biogas per day. This is, so far, the biggest manure-based biogas plant in Japan [33]. According to the project proposal by Okoppe town, this facility also indicate that many future biogas plants most likely will be established as Centralized plants, and that more manure will be a part of the feedstock mix in the future [46]. In Shihoro town, there are currently 11 Farm biogas plants at individual dairy farms, but one more plant will be established and be collectively utilized by three dairy farmers having problems with excessively amounts of manure, but willing to benefit from selling electricity under the FIT. Furthermore, Shihoro Agricultural Cooperative have also made agreement with eight plant managers to buy electricity to be utilized within e.g. the cooperative's office building, food processing factory [31].

Thus, more manure will be utilized as feedstock in future Centralized biogas plants in Japan, and recently, a number of both Farm and Centralized biogas plants have also experimented with feedstock like rape oil seed, wasted oil, strained lees of tomato juice, seafood residues - and other types of wastes, mainly from food industries and households [5] - implying that more diversity in the feedstock utilization will be applied in the future.

As far as increasing the market for biogas by e.g. excess heat distribution, or by other means of biogas usage, this is still relative limited in Japan. Upgrading biogas has not been utilized yet, but in e.g. Shikaoi and Bestukai upgraded biogas for transportation purposes has been applied on an experimental basis [31], [47]. As mentioned earlier the biogas plant in Shikaoi distribute excess heat to a greenhouse and fish tanks, and hereby minimize waste heat, indicating that more efficient use of heat will be included in future biogas planning to improve the plant economy and to obtain a more energy efficient biogas production [31].

6. CONCLUSION

In this concluding part we will, firstly, elaborate on the expansion opportunities of the biogas technology within Denmark and Japan, hereunder the areas to focus on in achieving this. Secondly, we will shortly propose how to improve the framework conditions and support to the biogas sector from various stakeholders connected to the previous findings.

6.1 Expansion opportunities

The analysis show that available feedstock for biogas production exists within both Denmark and Japan from livestock manure - especially from dairy and swine production - and that only a small fraction of this manure is used as feedstock in biogas plants for production of energy and high value fertilizer. Moreover, additional feedstock can be supplied to increase the gas yield and waste management; in Denmark e.g. grass, wheat straw, deep litter, organic waste from commerce and household, etc., and in Japan e.g. rice straw, excreta, MSW, sludge etc. In both countries, new types of feedstock are being tested, and in Denmark pre-treatment technologies for such feedstock's is also demonstrated and applied to increase the usability of such materials in order to increase the gas yield [13], [14]. For both countries apply - despite current initiatives - that more focus should be given to identify alternative feedstocks to secure a continuous growth within the biogas sector, so no future restrictions and rules will hamper the use of additional gas-rich feedstock.

In Denmark, there is a long tradition for utilizing raw as well as digested manure as soil fertilizer, but the decoupling of livestock and crop production systems within Japan, has resulted in a situation where the manure resources in some cases are wasted. Lack of cooperation between farmers, for example livestock farmers and crop producers, thus hamper utilization of digestate as fertilizer. It is partly due to the belief of many crop producers that chemical fertilizer is better than digestate in terms of high and stable yield. It will require further efforts by for example analyzing the chemical contents of digestate, and its effects on crop yield etc., and this knowledge will again need to be diffused by means of good communication with the extension services. Furthermore, a bad reputation among local residents obstructs the wide acceptance of digestate by crop producers. Japan has a high population density with farmland and residential area located very closely in some areas, which cause many residents to oppose to the spreading of digestate on nearby farmland. They regard digestate as raw manure. Therefore, communication and dissemination of the correct information on/to residents is vital to promote the utilization of digestate as fertilizer.

The production of energy in Denmark has historically been quite efficient due to the production of CHP and supply of DH. Biogas is now also distributed on the Ngas network, and secures an efficient use of energy in areas with a low heat demand. Still unfavorable framework conditions hamper that raw biogas can be distributed to e.g. a nearby industry with a large heat demand. By supporting this energy will be utilized more locally, secure collaboration between nearby stakeholders, and lower the use of fossil energy and thus CO_2 emissions within the local municipality.

In Japan energy production from biogas plants differs a lot compared to Denmark, and are in general not based on CHP production, but only limited and random distribution of excess heat. More focus should be given to increasing the energy efficiency and to identify markets for sale of gas and excess heat. Planning for heat distribution when deploying Centralized biogas plants in Japan should be included from the beginning; e.g. distributing heat to nearby farmers, local households or industries. Raw biogas can also be distributed to local industries, and raw biogas be utilized within the Japanese city-gas networks. This will not require Ngas upgrading and can be used in the existing city pipes, where up to 30 % raw biogas can be mixed with Ngas without negatively impacting the quality of city gas [48]. A more systematic mapping of energy and heat markets is hence necessary. In the following section suggestions are provided of how to increase the share of energy production from agricultural based biogas within both countries.

6.2 Improved framework conditions and support

Below, we have outlined important activities that need to be addressed by new governmental framework conditions and initiatives by research institutions, biogas planners e.g. technology developers and municipalities, gas companies and the agricultural sector, as well as other stakeholders involved in the deploying of biogas technology within Denmark and Japan:

- Continue and speed up research and demonstration programs in Denmark identifying alternative feedstock, their usability, hereunder pre-treatment options for obtaining high gas yield and effective waste treatment methods. Similar programs need to be started up in Japan.
- Support and disseminate knowledge about organic biogas to organic farmers and the agricultural sector in Denmark to enhance biogas deployment, and at the same time increase the area of organic farmland.
- Support cooperation between livestock and crop farmers in Japan regarding distribution of digestate as fertilizer & Set up targets for how much manure to digest and distribute before a specific timeframe.
- Educate and inform Japanese farmers, their organizations, as well as local residents, about the advantages of using digestate as fertilizer & Establish support programs to facilitate this.
- New markets for biogas distribution should be supported in Denmark by a FIT on export of raw biogas to nearby industry for internal process energy usage.
- Improve the energy efficiency on Japanese Centralized biogas plants by CHP production, which should be a requirement on new biogas plants being established. On Farm plants a certain percentage of the excess heat, if any, should be required utilized, e.g. send to nearby farmers or greenhouses, etc.
- Identification of heat markets in Japan should therefore be applied to facilitate the distribution of energy (excess heat) from biogas, with the purpose of increasing the overall energy efficiency and thus avoid heat losses.
- The government, municipalities and gas companies in Japan should promote the distribution and mix of raw biogas with city gas, and raw biogas to industry should be promoted.

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