RISK ASSESSMENT OF NUTRIENT DISCHARGES FROM BIOGAS PRODUCTION

- REPORT DENMARK

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1. List of all biogas installations in the country / region in question, divided by feedstock and size + year of deployment (Landfills and gasification not in focus)

Biogas is a very well developed technology in Denmark, with 74 manure based plants which all use co-digestion (collective and farm-scale) and 51 sewage based plants. Besides there are also a few industries with own biogas plants, and there are 27 landfills still collecting biogas, but the amount is steadily declining. The locations of the Danish plants are shown in figure 1. The greatest gas potential is found in manure-based biogas plants in agriculture, but wastewater plants also have possibilities for increasing the gas production by co-digestion with bio-waste, but until today this is only done on few plants.

The manure-based plants are currently counting 26 large collective plants and 48 farm biogas plants which use more than 10% of the manure. All the manure based plants are running after the principles of co-digestion and around 25% of co-substrates mainly coming from food processing industry are mixed with manure. The collective plants have capacities for the daily treatment of 100-2000 tonnes of manure and other biomass whereas the farm based plants have capacities ranging from 10-100 tons per day. The trend is towards larger facilities for both collective and farm based plants. Most of the farm scale and sewage based biogas plants are listed in Annex 1, where the capacity and year of installation can be seen.

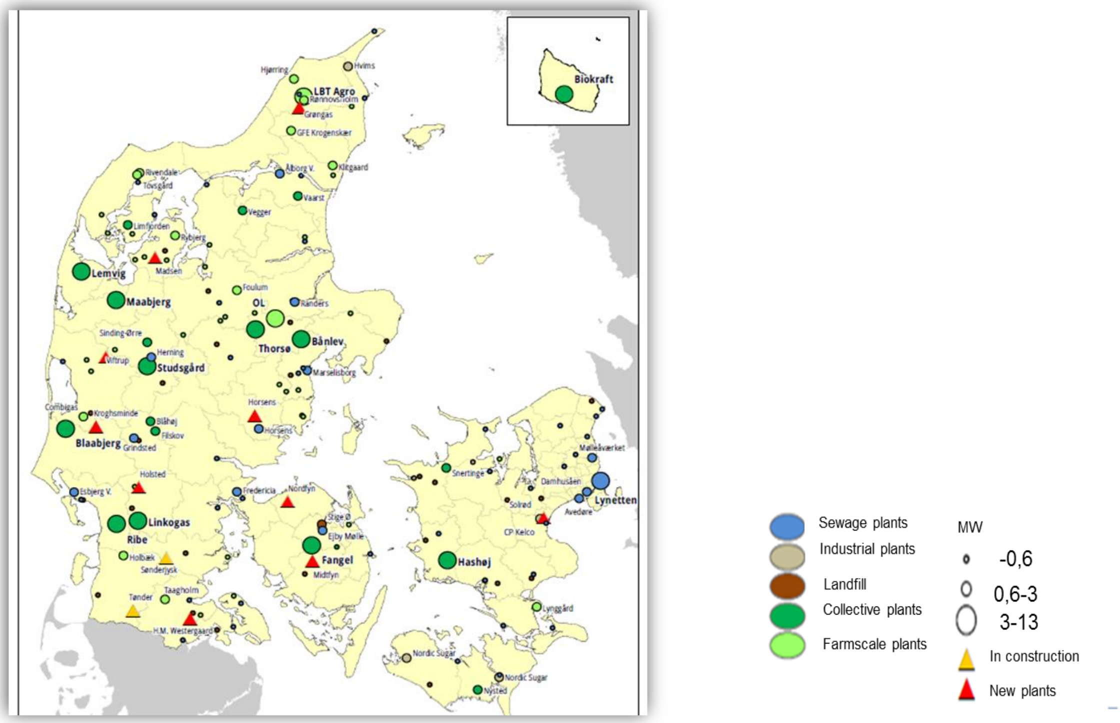
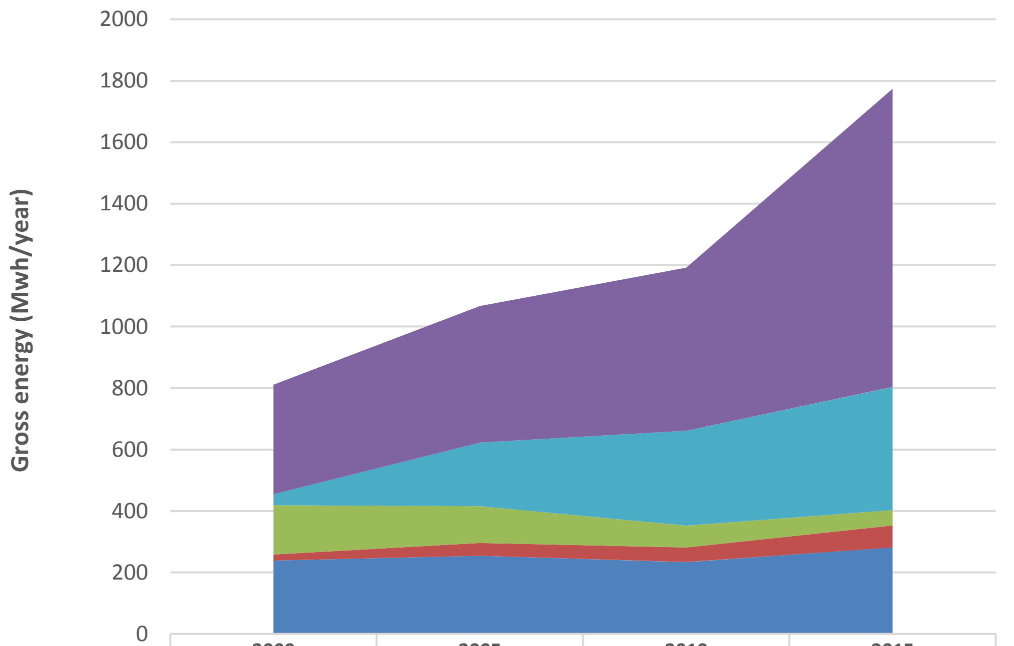


Figure 1. Map of existing and planned biogas plants in Denmark (Mikkelsen et al. 2016)

Total biogas production has risen from almost 800 Gwh in 2000 (figure 2) to almost 1800 Gwh in 2015. In 2016, production is expected to be around 2500 Gwh, and in 2017 a production of 3300 Gwh is expected. The huge expansion is driven by improved subsidies agreed in the Energy Agreement back in 2012, where biogas sold to the natural gas network is subsidized.



	2000	2005	2010	2015
Collective farmscale	356	444	531	970
farmscale	36	208	308	401
Landfills	160	119	71	50
Industrial plants	20	42	47	71
Sewage plants	239	254	234	282

Figure 2. Map of gross energy coming from different types of biogas plants in Denmark. The energy is in gross energy without subtracting own consumption at the plants. The farmscale and collective plants co-digest manure with waste.

The concept of collective biogas plants have been developed in Denmark since 1987 and the biomass mix used in these kind of plants and in the farmscale plants is shown in Figure 3. A few plants co-digest sewage sludge or the organic fraction of source-separated household waste, as well.

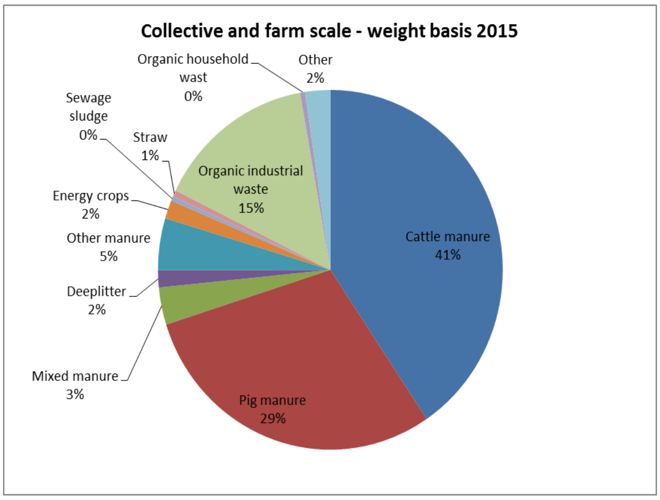


Figure 3. The biomass used in the collective and farm scale based biogasplants (Mikkelsen et al. 2016)

The biogas in Denmark is mainly used for combined heat and power generation, and the digested biomass is redistributed to a wide range of crops at farms.

However, in future more and more of the biogas will be upgraded for the natural gas grid. The status today and the expected development is shown in figure 4.

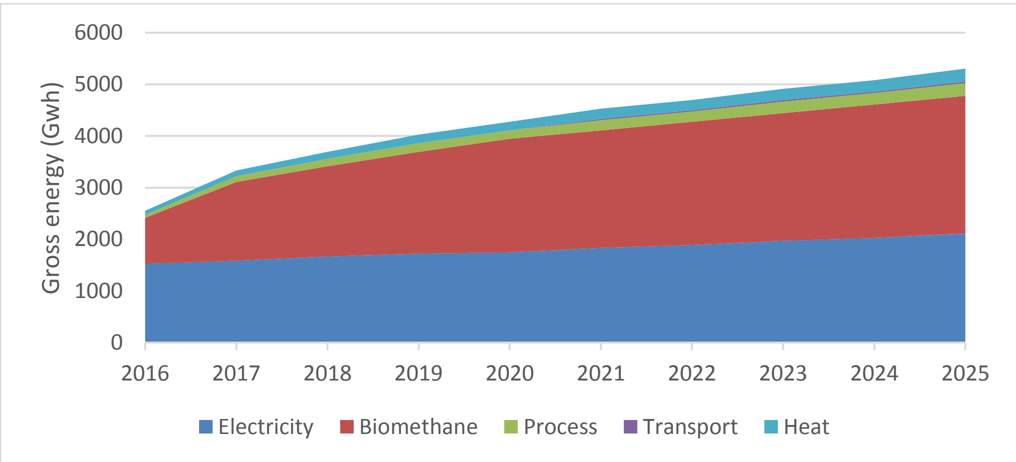


Figure 4. The use of biogas adapted from (Energistyrelsen, 2016)

The expected development of the biogas sector and the origin of gas is illustrated in figure 5 and it can be seen that almost all the future expansion is coming from the agricultural based biogas plants and overall only sewage based and agricultural based plants will contribute to the biogas production in future with a highly dominance from the agricultural plants.

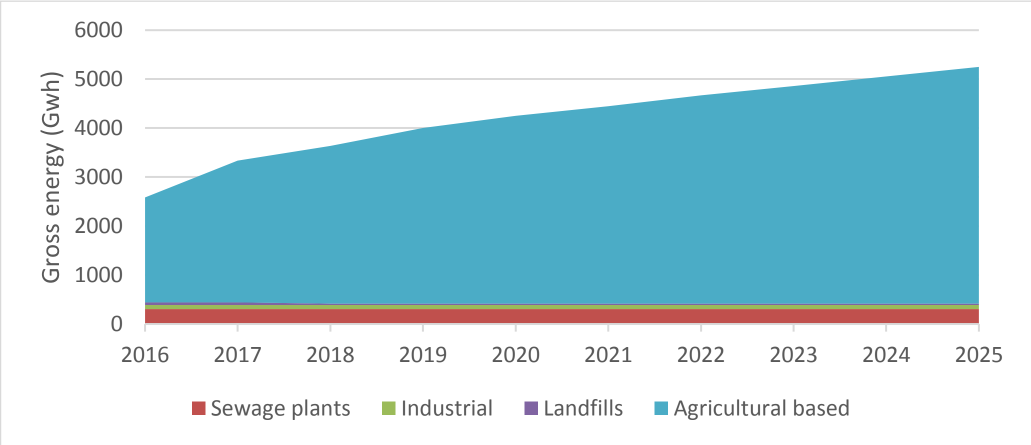


Figure 5. The prognosis of the amount of gas coming from different biogas types in future, adapted from (Energistyrelsen, 2016)

2. Review of treatment methods used for solid and liquid digestate from biogas processes and prevalence of different methods in the country in question

In Denmark the digestate from biogas plants are mainly used as fertilizer without any further treatment, but the methods for the use of digestate differs significant between the types of biogas plants and substrate used. Hence, the treatment and subsequent use of the digestate from sewage and manure based plants is very different. The digestates from manure based plants which all include co-substrates from industry is spread on agricultural land while only a part of the sewage sludge from WWTP is on agricultural land.

2.1 Sewage based biogas plants

In Denmark, approximately 750,000 tons of sewage sludge (BGORJ, 2015) are produced every year, at the municipal wastewater treatment plants. The wastewater is usually cleaned both mechanical, biological and chemical. After the process the sludge is often digested in biogas plants and subsequent it is dewatered by centrifuges or similar technology to a dry matter of 20-25% containing most of the phosphor and around 20% of the nitrogen. The sludge will subsequent be used as biological fertilizer in agriculture. The remaining nitrogen will be in the reject water and will be returned to the cleaning process where it is removed by nitrification/denitrification and is in general not causing any problems since the plants have been dimensioned for that.

Only one WWTP is treating household waste and this plant has been designed for it from the start and has very recently been completely rebuild so it is not taking in wastes that has not been part of the plant dimensioning. Several plants are looking at new innovative treatment like annamox, struvite etc. but only to save energy on existing technology not to comply with problems in treating reject water from biogasplants. In general almost all household waste will be used in the manure based plants so very little is used in WWTP

The sewage sludge from Danish WWTP's contains around 144.000 tons dry-matter (DM). In 2009 around 75.000 tons (52 %) where used in agriculture, 34.000 tons (24 %) was incinerated, 17.000 tons (12 %) was led to sludge mineralization, 835 tons (1 %) was deposited on landfill, 9.900 tons (7 %) was exported and 5.600 tons (4 %) used for other purposes (Miljøministeriet, 2013). In general sludge used in agriculture is used directly but after sanitation at 70^{o}C for 1 hour, but a small part is used after sludge mineralization which is an aerobic process improving the biological stability of the sludge.
In 2015 the share of the sludge used in agriculture as fertilizer has increased considerably and it is estimated, that 77% is used as fertilizer (BGORJ, 2015). The control of the use of sewage sludge is described in chapter 3.1. It is expected that the amount used in agriculture will be at the same level in 2016 and 2017.

2.2 Manure based biogas plants:

For the biogas plants dealing with agricultural by-products as main substrate almost all digestate is used without further treatment. All manure is spread on the fields there is no other options. Every kg of N and P need to be registered and the receiver need to sign and document a fertilizer plan for the authorities. The average composition of digestate for a number of plants is given in Table 1 (Møller and Nielsen, 2016).

There has been a lot of research in treatment of the digestate to fractions with high values, that can be sold, but due to a lack of legislation on use of phosphorous until 2017 the incentives have not be strong enough and until now only one plant separate the digestate and export the phosphor out of the region. However a new phosphor legislation being implemented in 2017, is expected to change this and there will be much more interest in solid-liquid separation to comply with the new legislation.

Maabjerg BioEnergy is the only plant that separate most of the digestate. The plant utilize a wide variety of biomass sources in the biogas plant:

- Manure from pigs, cattle, mink and poultry (85% of the amount of biomass)
- Industrial waste from dairies and slaughter houses (11%)
- Waste water (4%)

In total, around 640,000 tons of biomass is digested at the biogas plant and most of the digestate is separated in a solid and liquid fraction with a decanting centrifuge (Møller and Nielsen, 2016), with the aim to export excess phosphor out of the area, that have a large density of livestock production. The reason for this have been that for this plant the environmental permission requested that phosphor should be separated and used on land with low phosphor status to reduce phosphor surplus in the region.

Table 1: Composition of digestate as an average from 15 plants (Møller and Nielsen, 2016)

	Unit	Average	SD	Maks	Min
DM %	%	4,73	1,00	6,13	3,15
VS %	%	3,64	0,76	4,82	2,61
Aske %	%	1,52	1,27	4,67	0,57
Total N	g/kg	5,02	0,78	6,62	4,29
NH4-N	g/kg	3,03	0,86	5,27	1,95
Ca	g/kg	1,49	0,39	2,22	0,72
K	g/kg	2,84	0,93	5,67	1,66
Mg	g/kg	0,36	0,17	0,58	0,09
Na	g/kg	0,94	0,79	3,21	0,33
P	g/kg	0,81	0,27	1,57	0,48
S	g/kg	0,36	0,11	0,67	0,20

3. Legislative framework and permitting procedures for biogas installations

Back in 1985, the Danish government launched the NPO plan due to increasing problems with the water quality. The NPO plan set demands to harmony between the farmed area and the number of livestock, as well as to the minimum capacity for storage of livestock manure on farms.
Since then still tighter regulations from both the EU and Denmark have stimulated a technological development, with the result that today, the nitrogen (N) and phosphorus (P) in livestock manure is utilized with almost the same efficiency as that of mineral fertilizers, reducing the negative environmental impact of excess N and P loads at livestock farms, and farmers for costs for purchase of fertilizers. Below the different actions plans are listed from the first plan was launched in 1985:

1. NPO-action plan
2. Water Environment action Plan 1
3. 1987 – Nitrate directive (EU)
4. 1991 – water Environment action Plan 2
5. 1997 – Water Environment action Plan 3

6. 2004-15 – Water plans

3.1 Legislative frame work for use of digestate in agriculture

The fertilizer use of manure and digestate from manure based biogasplants are regulated by the rules in the order by Ministry of Environment and food (2016). There is a maximum amount of manure that can be applied per ha depending on the animal type (Table 2). Until 2017 the maximum amounts that could be applied where given in livestock units, but from 2017 it is given in kg of N per ha and the term livestock units are not used anymore. When using manure and digestate there is a minimum utilisation rate of nitrogen that should be obtained and every crop has its own fertilizer demand depending of soil type. The minimum utilisation rates are given in table 2.

Table 2: Application of livestock manure and minimum utilization rates.

	Minimum Nitrogen utilisation rate in fertilizer plan (minimum)	Harmony rules Maximum livestock LU/ha until 2017	Harmony rules Maximum livestock N kg/h (from 2017)
Pig manure	75 %	1.4	170
Cattle manure	70 %	1.7/(2.3[1])	170/230[1]
Deep litter	45 %	Like raw material	Like raw material
Other manure	65 %	Like raw material	Like raw material
Digested biomass	Like raw material	Like raw material	Like raw material
Declared Separated N-fractions	100%	(crop demand)	(crop demand)

[1]Only if more than 70% of the area is grown with beets and grass

The maximum amount of nitrogen that can be applied, is given by Ministry of Environment- and Food (2016) and depends on crop and soil type.

Until 2017 there has been no regulation concerning utilisation of phosphor in manure but from 1st of august 2017 a new P legislation has been implemented, as can be seen in table 4. The reason for the new P regulation is that Danish farmers have had much more strict regulation than the rest of EU. The pig producers have only had the possibility to apply 140 kg N/ha per year whereas the rest of EU could spread 170 kg N/ha. Therefore there has been a strong wish from Danish farmers not to have more strict regulation than the rest of the EU. After many years discussion about this the government finally decided to align regulation with rest of EU, if that could be done without environmental drawback and it was concluded that if a P regulation was implemented the risks would be diminished. Hence the reason for the P regulation was that with livestock producers even though already having reduced the over dosage of P load the new regulation would draw back this positive development.

Table 4: Limits on P application with manure implemented from 2017.

Animal type	**Maximum amount of P**
Poultry and Fur animal	43 kg P/ha
Fattening pigs	39 kg P/ha
Sows and piglets	35 kg P/ha
Cattles	30 kg P/ha
Cattles (230 kg N/ha)	35 kg P/ha
Digestate from biogas	As the input
Chemical fertilizer	30 kg P/ha

When producing biogas on agricultural based biogas plants there are rules regarding the amount allowed to be added of first and second generation biomasses. First generation energy crops are defined as biomasses, which can be used directly as food, where second generation are defined as biomasses, which is by-products like manure, straw, wastes etc. There is limits on how much of first generation biomass that can be used for biogas production for each plant. The following limits are allowed:

- 2015-2017: Maximum 25% energy crops measured as weight-input.
- 2018-2020: Lowered to maximum 12%.
- 2021: Depends on an evaluation after 2018.

Today it is permitted to add 25% first order energy crops such as corn, beet, and cereal like wheat, but already from the beginning of next year, this limit is lowered to 12%. After 2018, an evaluation is made to see which effect the changes have had to decide what should happen after 2020. It is expected that the limit of first generation energy crops will be lowered further (Energistyrelsen, 2014).

The use of sewage sludge and waste products other than manure are controlled by the regulations given by Ministry of Environment- and Food (2006). In areas supplied with waste, the total supply of nutrients in the form of waste and manure must not exceed 170 kg total nitrogen and 30 kg total phosphorus per. ha pr. year. Phosphorus dosage can be calculated as an average over 3 years. In forests, phosphorus dosing can be calculated as an average over 10 years. The regulation also give maximum values on heavy metals and other pollutants (Table 5). Waste products used as co-substrates in biogas plants have to comply with the same restrictions before they can be added to the biogas plant.

Table 5: Maximum legal contents of heavy metals

	Maximum content	
	mg pr. kg drymatter	mg pr. kg Phosphor
Cadmium	0,8	100
Mercury	0,8	200
Lead	120	10.000
Nickel	30	2.500
Chromium	100	
Zink	4.000	
Cupper	1.000	

Most sewage treatment plants have agreement with a company, who specializes in making contracts, quality assurance and marketing sewage sludge. It is often the same companies, that are responsible for transporting the sewage sludge, make analyzes and ensure quality. All sewage sludge is analyzed for nutrients, dry matter, heavy metals and environmentally hazardous substances.

In Denmark, the use of sewage sludge is covered by very strict environmental legislation compared to many other countries in EU. There is a resource recovery strategy aiming at recycling P from wastewater treatment and there ia an expectation that 80% will be recycled by 2018. Before the farmer can receive sewage sludge, it must be analyzed and only when the quality is known and complies with the requirements of the law farmers can receive it. The spreading fields are recorded on a card and the documents sent to the municipality's Agricultural Inspectorate, ensuring that all requirements are respected. In general there is worries about pollutants like flame retardants, microplast etc. but conclusions from all the risk analysis still don’t change the overall political opinion that wwpt sludges shall be used as fertilizer in agriculture to save import of P. DK import 18.000 tons P per year and the wwtp sludge reduce this import with 2400 tons per year. The sludge is used on 80.000 ha which is 3% of the total Danish agricultural area. Every year producers and end-users fill in fertilizer plans that is strictly controlled.

3.1 Legislative frame work for permitting a new biogasplant

Before stating up building a new biogas installation several laws and regulations have to be followed. When starting new projects the owner needs to follow the legislation. The first step is to send a written notification of the whole project idea to the responsible municipality. In this notification, there must be a comprehensive description of the biogas installation, related spreading areas for the bio-slurry and possible environmental side effects. Based on this notification the municipality assess whether there is a more detailed VVM statement needed (evaluation of impact on environment). This VVM statement is a procedure needed, when a project are expected to have significant impacts on the environment. The Nature and Environmental Complaints Board has a practice that projects with more than 100 tons of input per day is covered by the VVM which implies a mandatory VVM permission and since most biogas plants have a capacity above 100 tons/day, most biogas plants will need a VVM permission (Tybirk, 2014). Besides the VVM statement other regulation and laws need to be followed before construction with the Environmental protection law and the planning law being the most important.

Planning law

As part of achieving the goal of a significant expansion of biogas production, it has been a state requirement that there should be planned for joint biogas plants in the municipal plans. Therefore, most municipalities have now appointed areas for common biogas plants. If the municipality has issued areas for the establishment of biogas facilities in their municipal plan, and have prepared a local plan for this purpose, the initiators of a biogas plant can directly start the VVM process. In cases where farmers/biogas players wish to establish a biogas plant in the open country outside the designated ones there must be a municipal plan and local plan process in addition to the mandatory VVM.

Environmental protection law

The purpose of the law is to prevent and limit pollution. Furthermore, the law contributes to protection of nature and the environment. A biogas plant with a capacity larger than 30 ton biomass per day is covered by the environmental protection law and an environmental approval from the municipality is requested.

Animal byproduct regulation

Since there is a health and environmental risk related to use of by-products from animals due to potential pathogens a plan of how to handle the byproducts need to be approved by veterinarians.

4. Risk assessment with case examples of installations with potential adverse environmental impacts (and possibly case examples of solved problems if any)

The status of both nitrogen and phosphor excess has improved significant in Denmark and the development in phosphor balance from 2005 to 2013 (Andersen, H.E. et al. 2016) can be seen in figure 6.

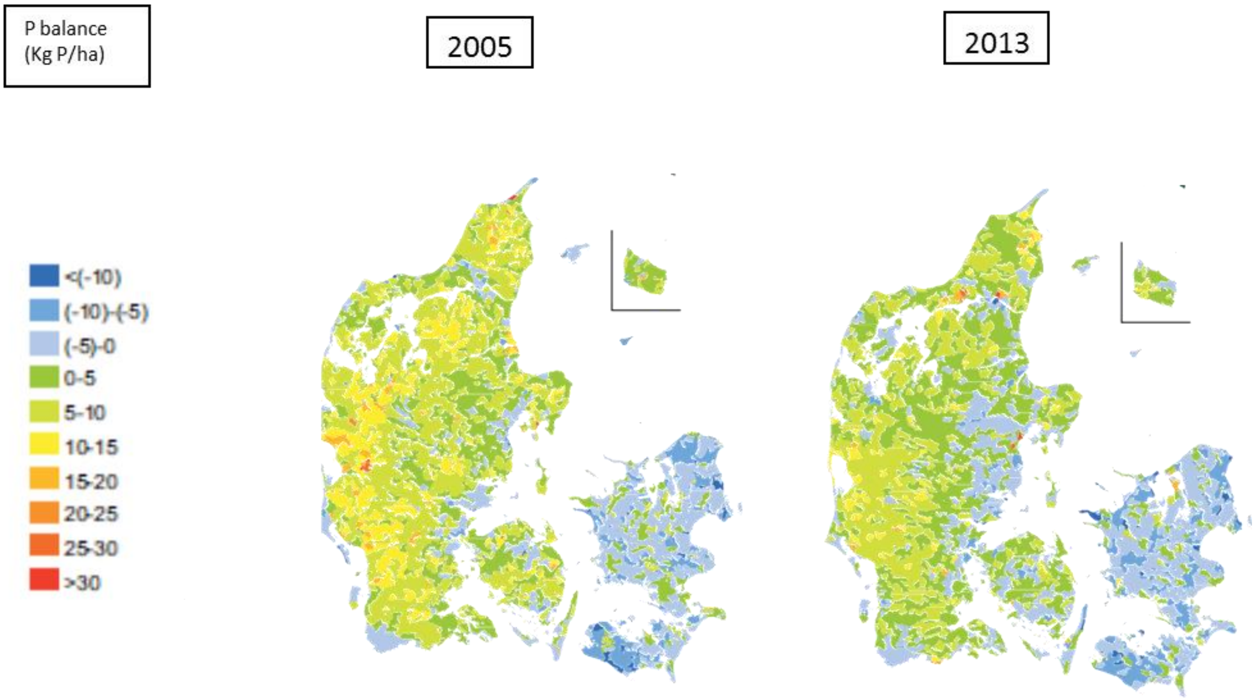


Figure 6. Phosphor balance in Denmark. The phosphor excess is calculated as the applied minus the P uptake on 15 km^2 plots (Andersen, H.E. et al. 2016).

In the eastern part of Denmark many areas connected to the Baltic sea have a deficit of P, meaning that the P status of the soil will gradually decline. In general Denmark still import a lot of P so there is no national surplus of P from manure and waste it's only a matter of distribution. The high use of WWTP sludge in Denmark only has a minor impact on the national balance and is mainly used in areas with low animal density since transport costs are not regarded as an obstacle. In animal dense areas in Denmark there is still a phosphor surplus but with the implementation of the new phosphor limits this is expected to decrease.

For biogas in general there has been no examples of installations with adverse impacts of the environment during normal operation. However, until 2017 there has not been any regulation on amount of phosphor application with manure and digestate meaning that if the nitrogen to phosphor ratio is lowered in the digestate by addition of waste products rich in phosphor, there has been a risk that the application of phosphor has been higher than the crop demand and the excess can be higher than when applying untreated manure in a reference scenario without biogas. There is however no examples that this has been the case until now and with the new phosphor regulation implemented from 2017, there is no risk that the biogasplant will have such an adverse impact.

Sewage based biogas

For the sewage sector the biogas plants serves as a technology that improve the overall performance of the sewage treatment since it reduces the amount of sludge that should be disposed and makes the whole system less energy consuming. Therefore the biogas system only have a positive impact. In case of including biowaste in sewage based plants there is an increased demand for the cleaning capacity of the plants since some of the nutrients from the biogas plants especially NH_4-N. To avoid any adverse environmental impact from waste that might be included in the future the cleaning capacity of the plant should be increased.

Manure based biogas

In general the many legislation and control procedures around biogas production ensures that there is no observed adverse environmental impact and biogas is seen as a solution for several environmental problems in relation to livestock production especially in relation to reduction of nitrate pollution and better distribution of phosphor. Furthermore the manure based biogasplant is seen as efficient way to recycle organic waste from food industry and society in a sustainable way.

Until 2017 there has been no regulation with phosphor dosage on agricultural land but from 2017 this will be the case. However since the biogasplant has a very well developed distribution system for digestate the phosphor in general have been distributed better, than has been the case with untreated manure, where considerable excess surplus has been spread on land close to the livestock units.

5. Subsidies and profitability (e.g. gate fees, electricity sold out) of production

The current biogas support system was agreed in connection with Energy Agreement 2012 (Folketinget, 2012), which is valid until 2020. During the period 2010 - 2012, investments grants were awarded to biogas plants under the rural development program. Support for the use of biogas for power generation, upgrading for supply to the natural gas grid, transport, process and heating purposes is provided today.

Table 6. Overview of the composition of biogas support (Folketinget, 2012).

Subsidy	Basic subsidy	Add. Subsidy regulated according to natural gas price	Add. subsidy reduced gradually until 2020
Biomethane	79 kr/GJ[1]	26 kr/GJ[2]	10 kr/GJ[3]
Proces	39 kr/GJ[4]	26 kr/GJ[2]	10 kr/GJ[3]
Transport	39 kr/GJ[4]	26 kr/GJ[2]	10 kr/GJ[3]
Heat	-	26 kr/GJ[2]	10 kr/GJ[3]
Electricity:			
Fixed price (incl. Electricity price)	0,793 kr/kWh[4]	0.26 kr/kWh[5]	0,10 kr/kWh[6]
Pris additional (excl. Electricity price	0,431 kr/kWh[7]	0,26 kr/kWh[5]	0,10 kr/kWh[6]

[1]79kr/GJ, 60% index regulated every year from 2013.
[2]Additional 26kr/GJ. The grant will be adjusted (up and down) for natural gas price (basis 53,2 kr/GJ)
[3]Additional 10kr/GJ. The grant will be reduced with 2 kr/GJ per year from 1/1 2016.
[4]100% biogas: 0,793 kr/kwh electricity, 60% index regulated every year from 2013.
[5]Additional 0,26kr/kwh electricity. The grant will be adjusted for natural gas price (basis 53,2 kr/GJ)
[6]Additional 0,10kr/kwh electricity. The grant will be reduced with 0,02 kr/kwh per year from 1/1 2016.
[7]>100% biogas: 0,431 kr/kwh electricity, 60% index regulated every year from 2013.

With the current subsidies there is a very high interest in investing in the biogas sector leading to a very rapid expansion with new biogas plants. Before introducing the high subsidies there has been a balance between supply and demand of co-substrates from food industry and in some cases there has been a small gate fee. However with the fast expansion of new manure based biogas plants with the need for co-substrates to make a higher profit there is a strong competition for substrates from food industry and to day most biogas plants pay a high fee to get access to these wastes. The digestate is in most cases transported to crop producers paying a small fee covering part of the transport and storage.

6. Case examples (if any) of commercial products from digestates (fertilizers, substrates for industrial processes)

The livestock concentration in Denmark is varying between regions and there is a huge interest in transporting excess nutrients from the most livestock dense areas to areas with more arable agriculture. For this reason, there has been several initiatives where manure is separated in a solid and liquid fraction where the aim is to concentrate especially the phosphor in the solid fraction making it more profitable to transport. However, due to pure profitability for the biogasplants caused by low market value of the solid fraction, most of the plants initiating this has later abandoned the technology, since there has not been any regulation on phosphor until now. However in future new phosphor regulation is expected to stimulate several new projects with separation and production of a phosphor rich fraction.

Måbjerg BioEnegy, one of the biggest biogas plants in Denmark has since the start separated most of the digestate in a liquid and phosphor rich solid fraction and subsequent sold the solid fraction to farmers in less livestock dense areas. The biogas plants has an environmental permission where they are obliged to do this, but from an economical point of view this is associated with a lot of cost and due to very low market price of the solids the biogas plants have a negative income from this.

7. Case examples (if any) of circular economy, where biogas is a part of a larger chain (e.g. combined chain of closed circle fish farming, use of nutrients in greenhouse vegetables production, biodiesel and biogas production, use of rejects in agriculture)

Besides a very successful use of liquid digestate as fertilizer in agriculture, there is full scale examples of circular economy where the products are used outside the agriculture sector. However, on research and demonstration scale there has been examples with production of liquid fertilizer for greenhouses and substrate for mushroom cultivation (AST concept). In organic farming there is a strong interest in using liquid digestate in greenhouses, but until now it is only done on research and demonstration scale.

Mushrooms are today produced in a traditional substrate made from composted straw and horse manure. During composting, 30 - 35% of the energy potential in straw and horse manure is lost and CO_2 and NH_3 are emitted. With the AST concept, biogas is produced instead and N is absorbed in N-enriched liquid fertilizer that can be used in green houses. The essence of the concept is that the fungi by means of enzymes degrade cellulose, lignin etc. in the substrate, so that the spent substrate can be used as pre-treated raw material for the production of more biogas. In short, what is not utilized in biogas plants is transferred to the mushrooms and what they do not utilize gets another trip in biogas plants. From all Danish manure-based biogas plants there are residual fibers that can be the starting point for the New Substrate. The technology is still under test, but the potential for a sustainable substrate is there. The substrate is supplied in compacted/pelleted form, so that only the water must be added to the fungus producer. This makes the substrate layer-resistant, easy to handle and can be transported and exported.

8. Solutions and proposals for mitigating adverse environmental impacts of biogas production with e.g. technologies for reject water or digestate treatment, enhanced digestate utilisation (processes, logistics), improved planning of biogas installations (locations, scale etc.), improved permitting procedures and legal or economic policy instruments

In Denmark there has been focus on using the manure based biogas plant for reducing environmental problems with nutrient losses from use of manure and having a high GHG mitigation. For this reason the legislation and economic policy instruments has often been changed whenever there is a risk of adverse environmental impacts by introducing new subsidies, new livestock production regulations etc. The two most reason examples of this was when the increased subsidy for the energy for biogas was introduced in 2012 and when the livestock manure application was aligned with EU regulations in 2017.

The first example was when the new improved tariffs for energy from biogas was introduced in 2012, the cultivation and use of energycrops was getting profitable for the biogasplants. However since the aim of the higher tariffs was to improve CO2 mitigation from manure and reduce nutrient losses from agriculture the use of crops would undermine this. To avoid this and not having the same situation as in Germany, where most of the substrate in the agricultural biogas plants was maize with no positive GHG mitigation and nutrient loss reduction potential, a new legislation was introduced to put a maximum of co-substrates in the form of energy crops. This was to ensure the sustainability of the plants. The amount of agricultural crops that can be used, was therefore limited to 25% (2017) with a further reduction of crops to 12% from 2018.

The second example was when the amount of livestock manure that could be used in Denmark, was aligned with other European countries in 2017. Until 2017 the amount of pig manure that could be spread on agricultural land was more strict in Denmark than in all other European countries (Nitrate directive), thus Danish pig producers could only spread 140 kg N/ha where the rest of Europe could use 170 kg N/ha. The consequences of aligning with the rest of Europe would however be an increased phosphor surplus and for this reason a limit of phosphor application was introduced to avoid any adverse environmental impact and to improve the situation even more than before introducing this.

Litterature

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Annex 1

Biogas plants in Denmark. The capacities given are the output of energy in the form of methane. A: less than 0,6 MW, B: 0,6-3 MW, C>3 MW

Installation	Feedstock	Size/capacity	Year of deployment
Rensningsanlæg Lynetten	Sewage sludge	B	Before 2000
Damhusåen Renseanlæg		A	Before 2000
Spildevandscenter Avedøre		B	Before 2000
Mølleåværket, Lundtofte		A	Before 2000
Stavnsholt Renseanlæg, Farum		A	Before 2000
Måløv Renseanlæg		A	Before 2000
Helsingør Renseanlæg		A	Before 2000
Sydkystens Renseanlæg i Espergærde		A	Before 2000
Hillerød Centralrenseanlæg		A	Before 2000
Usserød Renseanlæg, Hørsholm		A	Before 2000
Køge Renseanlæg		A	Before 2000
Roskilde Renseanlæg, Bjergmarken		A	Before 2000
Holbæk Renseanlæg		A	Before 2000
Nykøbing S. Renseanlæg		A	Before 2000
Slagelse Renseanlæg, Dalsvinget		A	Before 2000
Faxe Renseanlæg		A	Before 2000
Stege Renseanlæg		A	Before 2000
Næstved Centralrenseanlæg		A	Before 2000
Vordingborg Renseanlæg		A	Before 2000
Nykøbing F. Renseanlæg		A	Before 2000
Nyborg Renseanlæg		A	Before 2000
Ejby Mølle Renseanlæg		A	Before 2000
Middelfart Centralrenseanlæg		A	Before 2000
Bov Renseanlæg, Kruså		A	Before 2000
Gråsten Renseanlæg		A	Before 2000
Sønderborg Renseanlæg		A	Before 2000
Nordborg Renseanlæg, Himmark		A	Before 2000
Aabenraa Renseanlæg, Stegholt		A	Before 2000
Kolding Renseanlæg		A	Before 2000

Fredericia Spildevand		B	Before 2000
Vejle Centralrenseanlæg		A	Before 2000
Horsens Centralrenseanlæg		B	Before 2000
Grindsted Renseanlæg, Billund Energi		B	Before 2000
Esbjerg Vest Renseanlæg		A	Before 2000
Esbjerg Øst Renseanlæg		A	Before 2000
Ringkøbing Rensningsanlæg		A	Before 2000
Herning Renseanlæg		B	Before 2000
Søholt Renseanlæg, Silkeborg		B	Before 2000
Marselisborg Renseværk		B	Before 2000
Viby Renseanlæg, Århus		B	Before 2000
Åby Renseanlæg, Århus		A	Before 2000
Randers Centralrenseanlæg		A	Before 2000
Mariagerfjord Renseanlæg		A	Before 2000
Viborg Centralrenseanlæg i Bruunshåb		A	Before 2000
Thisted Rensningsanlæg		A	Before 2000
Løgstør Renseanlæg		A	Before 2000
Ålborg Vest Renseanlæg		A	Before 2000
Ålborg Øst Renseanlæg		A	Before 2000
Hjørring Renseanlæg		A	Before 2000
Frederikshavn Centralrenseanlæg		A	Before 2000
Skagen Renseanlæg		A	Before 2000
Herning Bioenergi, Sinding-Ørre	Collective manure based:	C	**1989**
Fangel Bioenergi		C	**1989**
Ribe Biogas		C	**1990**
Linko Gas		C	**1990**
Lemvig Biogasanlæg		C	**1991**
Hashøj Biogas		C	**1995**
Thorsø Miljø- & Biogasanlæg		C	**1998**
Bånlev Biogas		C	**1996**
Filskov Energiselskab		C	**1998**
Herning Bioenergi, Studsgård		C	**1995**
Blaabjerg Biogas		C	**1996**

Snertinge, Føllenslev Energiselskab		C	1997
Blåhøj Energiselskab		C	1996
NGF Nature Energy Vaarst		C	1998
Nysted Biogas		C	1997
Biokraft		C	1998
Limfjordens Bioenergi		C	2000
Maabjerg Bioenergy		C	2000
Horsens Bioenergi		C	2016
NGF Nature Energy Holsted		C	2016
Grøngas Vrå		C	2017
Solrød Biogas		C	2017
NGF Nature Energy Midtfyn		C	2016
NGF Nature Energy Nordfyn		C	2017
Sønderjysk Biogas		C	2017
Månsson		C	2017
Korskro		C	2017
Raade Biogas	Farm scale based:	A	Before 2000
Tousgård, Skinnerup		B	Before 2000
Houmarken, Gosmer Biogas		A	Before 2000
Rivendale, Hillerslev		B	Before 2000
Brunshøjgaard		B	Before 2000
Fårborggård		B	Before 2000
Nr. Rind Biogas, Bækagergård		B	Before 2000
Brdr. Thorsen Biogas, Nimtofte		B	Before 2000
Hemmet Bioenergi		B	2010
Hegndal, Hemmet Bioenergi		B	Before 2000
Uhrenholtgaard, Hadsund		B	Before 2000
Tinggård, Bedsted Thy		B	Before 2000
Klitgaard, Ulsted Biogas		B	Before 2000
Badsbjerg, Ulsted Biogas		B	Before 2000
Rybjerg Biogas		B	2017
Tågholm Biogas		B	2017
Møllegården		B	Before 2000

Lynggård Biogas, Fjellebro		B	Before 2000
Dølbygaard		B	Before 2000
Sindal Biogas		B	Before 2000
BB-Biogas		B	Before 2000
Lykkeslund Bioenergi		B	Before 2000
Grønhøj Bioenergi		B	Before 2000
Grøngas, Hjørring		B	Before 2000
Bramshøj, Spøttrup		B	Before 2000
OL Biogas		B	Before 2000
Rønnovsholm		B	Before 2000
Brandstrup, Rødkærsbro		B	2017
Rønge Biogas		B	Before 2000
Tumbøl Biogas		B	Before 2000