

“Turning Pig manure from Waste to Asset”

“Best Available Technologies to reduce nutrients leaching to the Baltic Sea”

Content

“Turning Pig manure from Waste to Asset”	1
“Best Available Technologies to reduce nutrients leaching to the Baltic Sea”	1
Key Messages	2
Introduction	4
Background	5
Best Available Technologies for Manure Treatment – Anaerobic Digestion, Separation and Manure Management	5
Recommendations to optimize technical setup of biogas plants	6
Recommendations to optimize nutrient recirculation	7
Recommendations to optimize the economic performance of biogas plant	9
Requirements on framework conditions for optimal benefit of manure based biogas production and separation	9
How to order the Technical Reports	10

Key Messages

Manure based biogas production has many benefits; one of them is the potential to reduce nutrient loads to the Baltic Sea from intensive livestock production. The positive societal and environmental effects of manure based biogas justify nationally tailored financial incentives and public investments in relevant infrastructure in order to ensure the profitability for the investors. This paper outlines the main positive effects of manure based biogas, the prerequisites regarding management of digestate and the initiatives needed by farmers, business and policy makers.

Two research studies¹ have identified technologies for handling pig manure from intensive pig production in the Baltic Sea region in an optimal way. The technologies are selected with the main objective to reduce the pollution of nutrients to the aquatic environment, but the benefits of using the recommended setup of technologies are more diverse.

The studies conclude that nutrient discharges from intensive pig production can be reduced significantly if biogasification of pig manure is used in combination with separation technologies, and proper timing and technologies for spreading the digested manure. An effective utilization of the nutrients in manure for crop cultivation depends both on the setup of technologies and on management practices.

The research findings create a win - win situation for:

- *Farmers/Biogas plant owners* - improved bio-fertilizer, reduced costs for heating, diversified sources of income
- *Biogas companies/Technology suppliers* – a growing market
- *Society/Consumers* – less dependence on fossil fuels, recirculation of nutrients, less odour problems from pig-production, new job opportunities
- *Environment* - reduced greenhouse gas emissions, reduced leaching of nitrogen and phosphorus.

The many benefits for the environment and society motivate the development of national incentives to sustain pig manure based biogas production until these technologies are fully commercially viable.

Key recommendations to policy makers

- Develop national and European incentives to make pig manure based biogas production profitable in the short perspective (until the technologies are fully commercially viable).
- Include biogasification of pig manure and digestate management (as described below) as recommended manure treatment technologies for environmental approval of intensive pig production farms, in the IED directive and in national regulations.

¹ Best Available Technologies for Manure Treatment (Foged 2010), Best Available Technologies for Pig Manure Biogas Plants in the Baltic Sea Region (Frandsen et al. 2011), available at www.balticsea2020.org

- Regulate that use of manure as fertiliser is based on nutrient balances, to ensure minimized loss of nutrients to the environment and that manure is spread on growing crops in springtime when nutrient uptake is more efficient.
- Apply official fertilizer norms for maximum dosage of N and P, based on crops' needs and available plant nutrients in the soil.
- Develop official standard values for livestock manure for all types of livestock in the country describing the normal content of the important nutrients as a result of animal type, livestock housing system and manure handling system.

Key recommendations to pig farmers/biogas plant owners:

- Implement a technical solution which is optimal for the specific installation. Each technology and farm solution should reflect local and country specific opportunities and barriers.
- Cooperatively owned technology combinations should be considered if several medium sized farms are located relatively close.
- Combine pig manure with other animal manure types (i.e. cattle or poultry manure), manure fibres or other agricultural residues to improve the biogas production and hence the economy of biogas.
- Use the digestate only when optimal for crop growth.
- Evaluate the optimal use of the produced biogas dependent on local and national framework conditions to optimize economy of the plant.

Key recommendations for technology suppliers

- Continue development of technologies to improve their environmental and economic performance.
- Improve technology capabilities and capacities to reduce investment and production costs.
- Improve pre-treatment technologies of manure and suitable biogas co-substrates to achieve optimal gas production.

Introduction

The Baltic Sea is a brackish sea with a unique and sensitive ecosystem. More than 90 million people live in the water catchment area and benefit from the sea for recreation, food, transportation etcetera. Unfortunately, the Baltic Sea is also one of the most polluted seas in the world. Overload of nutrients, nitrogen and phosphorus, leaching from agriculture in the surrounding countries is of highest concern.

The large amount of manure produced at intensive livestock farms in the region is a significant source of nutrients. As meat consumption grows worldwide, including in the Baltic Sea Region, intensive livestock production is predicted to increase, and consequently the amounts of manure. Already today, nitrogen and phosphorus in livestock manure put on agricultural land exceeds nutrients from human households 3 to 4 times.

But, this problem can be reduced significantly if the nutrient and energy rich manure is treated as an asset rather than waste.

Baltic Sea 2020 has shown, through a series of research projects, that biogasification of pig manure in combination with separation (where relevant) and “best practices” for storage and spreading of manure can reduce losses of nutrients significantly. The nutrients in manure are upgraded; recirculation of nutrients to crop production facilitated and biogas is produced for heating, electricity or upgraded to bio-fuel.

These research findings create a win - win situation for:

- *Farmers/Biogas plant owners* - improved bio-fertilizer, reduced costs for heating, diversified sources of income, sanitation of the manure, less odour, better acceptance of the pig production
- *Biogas companies/Technology suppliers* – a growing market (due to more installations and biogas production)
- *Society/Consumers* – less dependence on fossil fuels, recirculation of nutrients, less odour problems from pig-production, new job opportunities
- *Environment* - reduced greenhouse gas emissions, reduced leaching of nitrogen and phosphorus.

In other words, the large quantities of pig manure available in the Baltic Sea watershed can be used as a natural resource for renewable energy and fertilizer and provide several socioeconomic benefits. However, there are several aspects to consider to ensure the full potential of manure and to minimize unwanted environmental effects.

This paper is based on three technical reports². It describes their overall conclusions on:

- The multi-benefits of biogasification of pig manure
- Best available biogas technologies and management practices
- Important measures to avoid losses of nutrients to air and water
- The relevance of adapted incentive structures to support suggested measures

Background, detailed descriptions and rationale for the identified technologies and management practices is available in the technical reports mentioned above.

Background

The consumption of pork is increasing worldwide and in Europe. While European slaughter index has decreased for cattle, sheep and goats since the 1990s, it has increased for pigs. The major pig breeding Member States in 2007 were Spain, France, the Netherlands, Denmark, Germany and Poland.

Livestock production used to go hand in hand with crop production. The nutrients in livestock manure were recirculated and used as fertilizer in the fields. Since the mid 70s, intensive livestock production has evolved. European farmers have become more specialized and livestock production, especially pig production, is not automatically coupled with fodder producing land.

Pig manure is furthermore relatively rich in phosphorus and overdosing with phosphorus (P) is therefore common when using pig manure as fertilizer. Decomposing pig manure also produces the greenhouse gas methane (CH₄) which risk evaporating to air during storing and spreading.

Best Available Technologies for Manure Treatment – Anaerobic Digestion, Separation and Manure Management

A recent research study initiated and funded by Baltic Sea 2020³ identified biogasification of pig manure, in combination with separation and improved management of manure, as cost effective methods to reduce leakage of nutrients. A follow up study⁴ has identified the best setup of biogas and separation technologies for pig manure.

Biogas is produced through anaerobic digestion when microbes convert organic matter to biogas (Methane, CH₄) and nutrient rich fertilizer – the digestate. During the biogas process, the organic nitrogen in the substrate is converted into a more readily available form for growing plants. Thus, the biogas process improves the fertilizing value of the treated substrates. Odour of treated manure is also reduced significantly.

² The reports are available at www.balticsea2020.org

- Best Available Technologies for Manure Treatment (Foged 2010)
- Cost Effective Phosphorus Management Measures (Foged 2010)
- Best Available Technologies for Pig Manure Biogas Plants in the Baltic Sea Region (Frandsen et al. 2011)

³ Best Available Technologies for Manure Treatment (Foged 2010)

⁴ Best Available Technologies for Pig Manure Biogas Plants in the Baltic Sea Region (Frandsen et al. 2011)

Separation of the digestate, into a dry fraction with most of the P and a liquid phase with most of the plant available N, allows for a balanced fertilization suitable to the crops. Safe storage of manure and timely fertilizing according to crops need for nutrients are key measures to utilize the natural nutrient resource in manure to its full potential, and avoid losses to air and water.

In general the studies conclude that for optimal environmental and economic output, the whole manure handling chain from the various stable systems should be analyzed and adjusted accordingly; manure pre-treatment, biogasification, post separation of digestate, manure/digestate storage and manure field application. To enable effective dosage of nutrients in digestate, national fertilizing norms and standard values for livestock manure must be available. Furthermore, treatment and use of produced biogas (Combined Heat and Power (CHP), upgrading, etc) should be considered in relation to national infrastructure, regulations and business opportunities.

Major conclusions from the reports:

- Biogasification of pig manure, where relevant in combination with separation, can reduce the leaching of nutrients significantly - provided that digestate is stored in covered containers and spread in springtime when plant uptake is efficient.
- Co-substrates, such as other manure types and agricultural residues, are often needed in order to make biogasification of pig manure profitable.
- Biogasification of pig manure, using the recommended setup of technologies, can contribute to European, Baltic Sea Region and national targets for water quality and renewable energy.
- A pig manure bonus or similar incentives is recommended to promote that a large proportion of the pig manure is treated through biogas plants. This bonus is needed to achieve the societal benefit of a cleaner environment with positive revenue for the farmer/biogas plant owner.

Recommendations to optimize technical setup of biogas plants

A number of technical considerations are required in the manure treatment technology setup in order to ensure the multiple benefits, e.g.:

- **Optimal plant construction.** The biogas plant should be constructed to optimize the biogas yields and mineralization of the manure nitrogen and co-substrates (where relevant). Technologies for pre-treatment and separation of the digestate should be considered.
- **Manure mixing.** Pig slurry can be mixed with cattle slurry, solid deep litter (pig or cattle), poultry manure and other agricultural residues to achieve a higher, more cost-efficient and more stable gas production. The nutrient content of such additional substrates must be correctly accounted for in the farm nutrient balance calculations to achieve the desired nutrient leaching reduction effect.
- **Fresh manure.** Manure should not be stored before biogasification (due to methane loss during storage).

- **Odour reduction.** Modern odour reducing equipment should be integrated in the construction, and the plant should in general be constructed and managed so that losses of methane and ammonia are kept at a minimum.

Recommendations to optimize nutrient recirculation

The challenge for pig farmers who aim to reduce their nutrient load to surrounding waters is to re-circulate the nutrients in manure as effectively as possible. A more efficient use of nutrients can benefit both farmers and water quality.

- **Post-separation and storage.** The digested manure should – where appropriate and economically feasible – be separated into a nitrogen rich liquid fraction and a phosphorus rich solid fraction. Separation allows for dosage of nitrogen and phosphorus according to the specific needs of plants

Both the liquid and solid fraction should be stored in closed containers to avoid emissions of ammonia and laughing gas, and large enough to allow for application to the fields in springtime.
- **Field application.** The digestate should be spread to fields during springtime when plant uptake of nutrients is efficient. Field application in autumn should be avoided.
 - The liquid phase of the digestate should be applied to fields belonging to concerned pig farms using the best technologies to avoid ammonia loss (trailing hoses, immediate incorporation, injection or acidification during field application).
 - The solid fraction should, if there is phosphorus surplus at the fields belonging to concerned pig farm(s), be transported to fields further away, applied using spreading equipment for solid manure and immediately incorporated into the soil.
- **Dosing of manure nitrogen and phosphorus** should be done according to the needs of the crops and soil analyses in accordance with official norms and standards to ensure profitable crop cultivation with minimum risk for phosphorus losses.

Ideally the risk for phosphorus losses should be estimated by the use of phosphorus indices⁵ and dosage of phosphorus adjusted accordingly.

Figure 1 illustrates in a simplified flowchart the fate of the manure nutrients in the recommended manure treatment approach. A pig farm which comply with the EU Nitrates Directive (maximum spreading of 170 kg N/ha and year) is assumed. The flowchart shows the amount of total nitrogen, organic bound nitrogen, mineralized nitrogen and phosphorous applied to the fields of the pig farm.

Pig slurry is used for biogas production and the digestate is separated into two fractions. The liquid fraction is used locally on the pig farm and the solid fraction is 'exported' to other fields outside the farm in need of the nutrient.

⁵ A P-index is a tool to analyze the relative risk of phosphorus loss at field level or larger units.

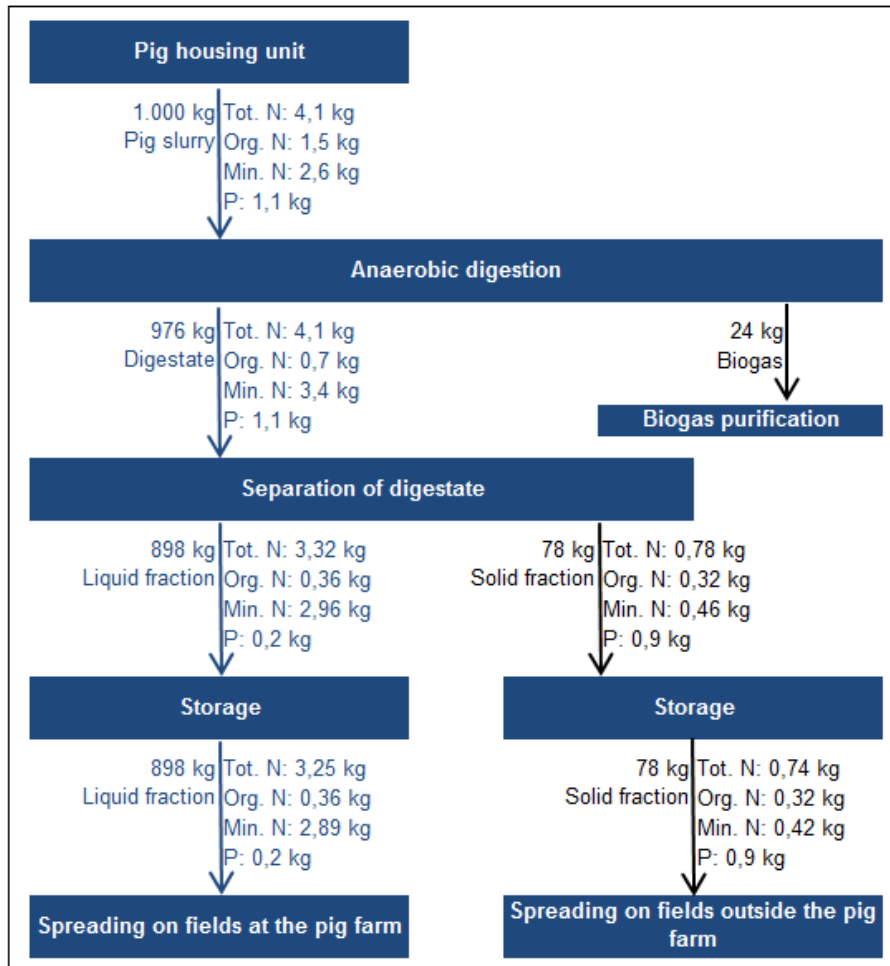


Figure 1. Simplified flow chart for optimal pig manure handling. Pig slurry is treated in a biogas plant, the digestate is separated and only the liquid fraction is applied to the fields of the pig farm.

The chart illustrates that the amount of organic bound nitrogen applied to the fields of the farm is reduced from 1.5 kg (without biogasification) to 0.36 kg for 1000 kg of pig slurry. Similarly it is seen that the amount of phosphorous applied to the fields of the farm can be reduced from 1.1 kg to 0.2 kg for 1000 kg of pig slurry. The separation enables the rest of the P to be 'exported' to other farms/fields in need of nutrients.

Co-digestion of additional substrates which would not otherwise have been used for fertilising will result in additional nutrients distributed to the fields. The use of additional substrates other than livestock manure, straw and discarded/un-used fodder residues can thereby prevent or reduce the desired positive effect of biogasification on reduced leaching of nutrients to water. If additional substrate nutrients are incorporated in the nutrient balance of the fields in a correct way (according to plant needs), the risk of over fertilization and leaching on the individual field may be avoided.

Recommendations to optimize the economic performance of biogas plant

Profitability is the overall driver for biogasification of pig manure. The economic performance of a biogas plant depends on several factors such as the optimal mixture and pre-treatment of intake biomass, optimal technological configuration, management and monitoring, and maximizing the value of the produced gas. The most important parameter for the business economy of biogas plants is the amount of produced gas/ton of intake substrate⁶. Gas yield can be increased by:

- mixing pig slurry with additional substrates, as mentioned above preferably with other types of livestock manure
- pre-treatment of slurry and additional substrates
- using fresh livestock manure (around 20% higher biogas production capacity than livestock manure which has been stored for just a few months)

The value of the produced gas is also important for the economy of the biogas plant, and it is important to exploit the most feasible use, whether for combined heat and power production, upgrading and use in the transport sector, for district heating or other.

Requirements on framework conditions for optimal benefit of manure based biogas production and separation

The outlined environmental, economic and climatic potentials of manure based biogas production and separation depend on national framework conditions, e.g.:

- **Official fertiliser norms and official standard values for livestock manure:** The benefit for the farmer of investing in biogas production and separation is apparent only if EU's agro-environmental legislation (or equivalent) is enforced, especially that official fertiliser norms and standard values for livestock manure exists and are enforced.
- **Infrastructure to connect biogas production with final energy consumers:** Biogas can be converted to energy in several ways, directly in boilers for heating purposes or steam production, for combined heat and power production, or it can be upgraded to bio-methane and used as vehicle fuel or injected into gas networks. The optimal use varies according to national infrastructure and subsidy systems:
 - Utilization of biogas for combined heat and power production is a well known technology and is in most countries the most profitable alternative due to feed-in tariffs on electricity.
 - In countries with tax systems favouring use of biogas for vehicles (i.e. Sweden and Germany) upgrading of biogas should be considered especially for medium and large scale biogas plants.

⁶ Based on Kogebog for etablering af biogas (Tybirk, K. (ed.) 2010.)

- Upgrading and injection into the gas grids, is a good alternative (where gas grids are present), as this resolves storage and distribution challenges.
- **Financial incentives to make biogas economically competitive:** External / societal benefits for the climate and the aquatic environment should be internalized in the form of subsidies to make the “manure – to – biogas” supply chain profitable. The society has numerous benefits from manure based biogas to justify incentives to make the business profitable for the involved actors in the supply chain.

A manure bonus as part of the national biogas incentive structures can provide competitive conditions for the manure based bio-energy chain. The support for manure based biogas should be adopted to fit the national/ local options in terms of infrastructure and energy market. It is a delicate balance to support the societal benefits through well adapted incentives which should make investments secure (long lasting incentives) and regulation flexible according to the evolving energy markets.

How to order the Technical Reports

The technical reports “Best Available Technologies for Manure Treatment”, “Cost Effective Phosphorus Management Measures” and “Best Available Technologies for Pig Manure Biogas Plants in the Baltic Sea Region” are available at the Baltic Sea 2020 website www.balticsea2020.org.

You can also send an email to info@balticsea2020.org and we will send you a copy within a few weeks