COSTS OF SLURRY SEPARATION TECHNOLOGIES AND ALTERNATIVE USE OF THE SOLID FRACTION FOR BIOGAS PRODUCTION OR BURNING - A DANISH PERSPECTIVE

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Abstract

Separation is an option when livestock are produced in livestock intensive areas producing a surplus of nutrients. Separation of the slurry into a liquid nitrogen rich fraction and a more solid phosphorus rich fraction, which is exported away from the farm, may alleviate this problem. Separation offers an alternative to exporting the slurry further away, renting more land or buying more land. Today the farmer can burn the solid fraction, use it in biogas plants or sell it to another farmer. At the same time the need for P-balance is stricter than before, but developments in feeding, regulation and the reduction of livestock numbers in Denmark have made separation less favourable. This article discusses the many options with focus on the dominant separation technologies in Denmark, such as decanter and flocculation, as well as source separation, in order to compare them with to traditional handling. Key parameters are livestock density, transport distance and cost of separation. The conclusion is that unless land prices or prices on slurry agreements are very high, traditional handling of animal manure has the lowest costs. Decanter separation can be the cheapest if area is limited and co-operation with neighbours is possible as large volumes reduce separation costs per tonne. Flocculation is the best if much P has to be stored in the solid fraction. Separation can be combined with biogas production and the solid fraction from flocculation seems to give the highest gas production per tonne.

Keywords: Slurry separation, costs, economics, separation technologies, solid fraction, burning, biogas

1. Introduction

In a number of regions in Europe the amount of animal manure is high compared to the agricultural land where it can be applied, leading to applications of nitrogen and phosphorus which exceed the crops requirements. These regions cover the Western part of Denmark, The Netherlands (especially the Southeast), Belgium, as well as parts of France and Spain (Brower, 1999). In order to comply with the Nitrate directive and the Water Framework directive (2000/60/EF) lower nutrient application is likely.

The largest part of slurry is water and it is natural to consider separation of slurry into fractions where the water fraction stays on the farm. This will e.g. reduce the transportation costs and perhaps storage costs (Burton, 1997). In case higher overall utilisation of nutrients in the fractions could be achieved, this would lead to lower purchase of mineral fertiliser. Separation will especially help to decrease the phosphorus load if the phosphorus rich fractions are exported away from the livestock intensive farms (Jacobsen et al., 2002b). Finally, the use of separation techniques might reduce the smell from pig production and lower the frequency of animal diseases from slurry as the process might reduce the number of harmful bacteria (pathogens). The solid fraction from the separation is well suited for biogas plants as the methane production increases with the dry matter content, but an alternative is to burn the solid fraction. With new environmental regulation requiring fewer livestock per hectare, separation is a way to maintain the current production at the present location with lower environmental impact.

From an economic perspective, any additional cost related to processing of slurry has to be recovered in one way or another. This can be through lower transportation costs or higher value of the end product. In other words, the total farm sector benefits have to exceed the costs of separation for it to be worthwhile. However, the benefit of using new technologies might include a transfer of income from the animal producer to the arable farmer.

The purpose of this paper is to analyse different separation concepts in order to evaluate the overall costs based on system approach from stable to field. The paper describes how regulatory changes (livestock density and burning) have changed the uptake of separation technologies, just as changes in feeding have had an impact. The paper also describes how separation might be combined with biogas production. Furthermore, the paper also looks at whether separation techniques can produce fractions which, on their own, can fulfil the nutrient requirements of the crops.

The paper starts with a short description of the development of the use of separation technologies in Denmark, which is one of the countries in Europe with the highest use of separation technologies. It then goes on to look at the purpose for using separation technologies and the legal restrictions. The paper then describes the costs and revenue related to using the three alternative technologies (decanter, flocculation, source separation) from stable to field on a large pig farm producing 18,000 finishing pigs a year. The effects on changes in land price, transport distance and land prices on the ranking of alternatives is discussed in the final section.

The paper includes an analysis of separation techniques including both the environmental and economic dimension, looking at the entire chain from stable to the field, with focus on nitrogen usages and phosphorus and the alternative use of the solid fraction.

2. Separation techniques and regulation in Denmark

In a Danish context, the separation technologies have been divided into “high technology separation” where the outcome is several fractions, of which one is almost pure water, and “low technology separation” which produced two fractions. The high technology technologies have been in the developing stages for a number of years, but the approach has been too costly and technically not consistent so the companies have closed down (e.g. Funki Manura and Green Farm Energy), leaving the market to simple but well tested technologies (Jacobsen et al., 2002b, Jacobsen and Hjorth-Gregersen, 2003).

In 2007, 944,000 tonne slurry was separated on 51 separation units in Denmark (Birkmose and Zinck, 2008). This is equivalent to 3% of the total amount of slurry. At all units the slurry is divided into a solid fraction and a liquid fraction. Half of the units were based on slurry from pig production, whereas the other half were based on slurry or degassed material from biogas plants where the raw slurry also might come from a pig farm. Often the liquid fraction is distributed on the local farm, whereas 44% of the solid fraction is exported to other farmers or to the biogas plant (31%). Only 3% of the solid fraction was burned and the rest is unknown. Most units were implemented between 2006-2007 partly because of a 40% investment subsidy in that period (Landscenter and KU, 2007). The Danish Farmers Advisory centre (Frandsen, 2010) estimates that of the units working today, 40% are screw press, 40% band filter and most of the rest decanter centrifuge.

This development fits in very well with the conclusion in the FOI report no. 142, which concluded that the high technologies plants were too expensive (Jacobsen et al., 2002b). The report showed that the handling of fractions requires new application technologies and focus on reducing the nitrogen loss at storage. Finally, the report points out that the alternative land price and the income from farming has to be large for even the low technology options to be a profitable alternative to longer transport or renting more land. The decanter separation units might be worthwhile as the total costs were lower, but the report pointed out that the lack of a market for the solid fraction was a major problem.

Since then, farmers have been more interested in receiving the solid fraction and it is used in more biogas plants. Furthermore, the high fertiliser prices in 2008-2009 led more farmers to be interested in receiving the solid fraction than before (see fiberdating.dk). Alternative use of the solid fraction is still limited (Jørgensen and Jensen, 2010). Another key factor in the implementation besides the technology and the economics is the regulation of livestock farms and the need to transport slurry further away.

2.1. Area required for animal farms in Denmark

The Danish legislation allows only a maximum of 1.4 livestock units (pigs) and 1.7 livestock units (dairy) per hectare (standard conditions). One livestock unit is 100 kg N (ab storage) and it was previously equal to one dairy cow, but is today equivalent to 0.75 dairy cows or 36 finishing pigs as the developments in feeding has been taken into account. The area needed for distribution of slurry needs to be owned, rented or guaranteed through 5 year slurry contracts. A given percentage of this distribution area needed have to be owned by the farmer, and this percentage use to increase with farm size. In figure 1, the top line shows the area required to have harmony between area and livestock production on a pig farm. The top dotted line shows how much of the area, required for harmony, which had to be owned by the farmer before 2006. This regulation has helped to avoid large excess of phosphorus as has been seen in some countries (e.g. The Netherlands).

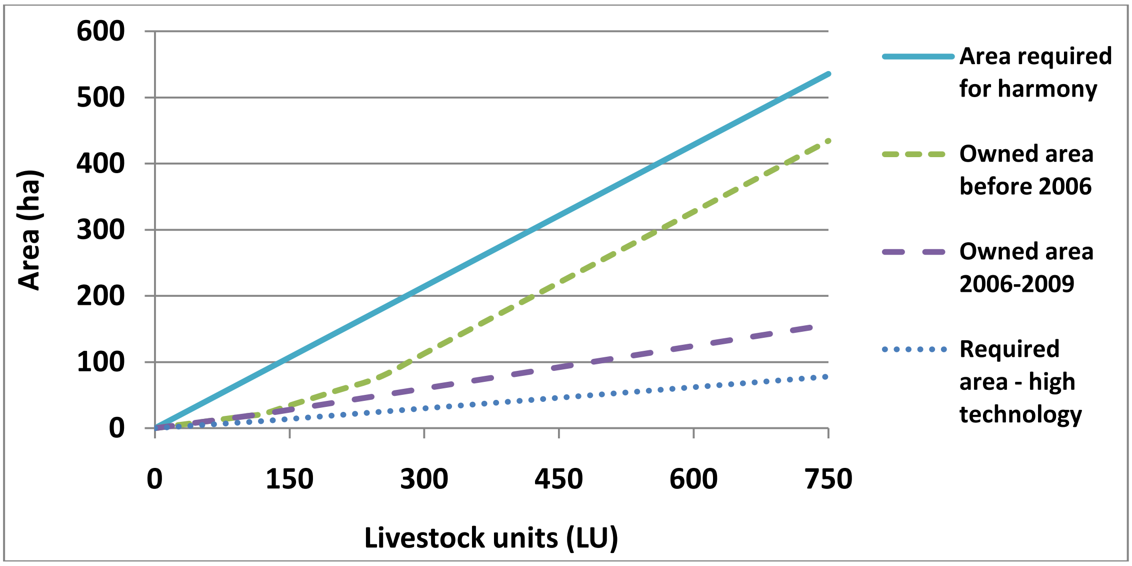

Figure 1. Area required for harmony on a pig farm according to Danish legislation
Source: Own calculations

In 2002, an incentive to promote separation was included, as the area requirement was reduced by 25 or 50% for the use of high and low separation technology respectively. The area requirement has since been relaxed again and has the 1st of April 2010 been removed (Anonyms, 2010) so now the farmer does not need to be the owner of the area as it can be rented. The conclusion is that the incentive to support separation in the period 2002-2009 probably did help to increase the number of separation systems implemented as the land prices at the same time were increasing. Furthermore, the relative low income in pig production in 2008-2010 has also worked against increasing the number of separation units. The total numbers of pigs has decreased by 10% from 14.0 million in fourth quarter in 2007 to 12.5 million in the third quarter in 2010 (Statistics Denmark, 2010). Also the total number of livestock has decreased by 400,000 livestock units to 2.1 million in 2009, which a decrease of 18%. Part of this reduction has happened because of the problems with getting approvals for new animal farms through the new electronic approval system introduced by the Environmental Agency (See www.husdyrgodkendelse.dk and Jacobsen, 2010).

The lower livestock density has reduced the need for separation technologies as land is easier to come by, which together with the financial crises has reduced land prices. On the other hand, farmers and biogas companies are more willing to buy separation products (solid fraction) than five years ago as they have realized the value of the products in the years with high fertiliser prices. However, the price for the fractions is still low, sometimes zero, even though the nutrient value per tonne is relatively high.

2.2. Burning the solid fraction

An alternative to selling the solid fraction is to burn this fraction. An analysis of the costs shows that there can be a little gain from burning the solid fraction if the produced heat can be fully used and the burning facility is a large scale operation (e.g. 62,000 tonne per year). In this case the heat is sold at 200 DKK per MWh (or 55 DKK per GJ). In case the burning is in combination with a biogas plant and with increased size of the facility, burning is even more profitable (FVM, 2005 and Hjorth-Gregersen and Christensen, 2005).

The solid fraction can only be burnt in an approved facility. Typically the large burning facilities already fulfil strict rules and have the advantage that they can take large quantities. To open up for use in farm separation plants the Danish Environmental agency would have had to classify the solid fraction as something other than waste. The conclusion is that in a Danish context the burning of the solid fraction is only possible at centralised plants. Apart from traditional burning, gasification is another option. The difference is that the substance is heated without oxygen and syngas is produced. Another issue is recycling of P which is a limited resource.

2.3. Separation and biogas

Biogas plants today try to use the solid fraction from separation in the production of biogas. The total energy production is higher when biogas and separation is combined. Today 6-7% of the slurry is treated in a biogas plant, but the Danish Government intentions are to increase this to 50% based on the Governments Green Growth Plan. Biogas plants are less profitable than before as the plants have to pay for e.g. fish oil and other gas busting ingredients (see Maarbjerg bioenergy, 2005 and Morsø Bioenergy, 2009). The advantage of using a biogas plant is the more balanced content of N and P, and also that the utilisation of N in digested slurry is higher (lower ammonia emission), it is free from germs and the smell is reduced. For biogas to expand in Denmark it is likely that the biogas has to be upgraded (no CO2) so that in can be distributed in the current natural gas net. The costs of using natural gas is around 2.3 DKK/m3 methane, but this price will increase to 4,0 DKK/m3 methane if it is produced based on slurry and to around 5.0 DKK / m3 if the methane produced has to be upgraded (Jensen, 2009). Others argue that with even conditions between biogas for heating locally and delivery to the natural gas net bio gas companies would soon be interested in using this option.

2.4. Reducing P-surplus

Reducing phosphorus surplus is another important reason behind the use of separation as the Danish environmental target is to reduce the P-surplus of 30,200 tonne P in 2001/2002 by 50% by 2015. The feeding practices are changing so that an average pig farm with 1.4 LU/ha today applies 25-30 kg P, where the crops require 20-25 kg P per. ha. In 2002, the feeding norms resulted in 37-44 kg P per ha based on 1,4 livestock units per ha and traditional feeding (MST, 2009a). This development has in other words reduced the need to use separation as a way to reduce P application at the farm level, but some areas might have to lower P application even more (Jensen, 2010).

3. Analysis of costs

For the purpose of this analysis, traditional handling of slurry is compared with separation in the stable, decanter separation and flocculation. With all the separation techniques, the end product is a liquid fraction and a solid fraction. The nutrient content will vary with the technology (see table 1). The separation can be carried out at the farm or at a centralised location (e.g. biogas plant), but in this analysis it is assumed to be carried out at the farm level either through a fixed separator or a mobile one. The analysis looks at the entire chain from stable to field and includes the costs for storage, separation, transport and additional purchase of mineral fertiliser to fulfil the nutrient requirement of the crops. Based on the description above, a number of relevant scenarios for the use separation techniques have been set up. They are (see appendix A for more detail):

Scenario 0: Traditional stable, storage and local distribution of slurry (203 and 357 ha)

Scenario 1: Traditional stable, separation (decanter) (stationary or mobile), farm use liquid fraction and transport and application of solid fraction (30 km) (203 ha)

Scenario 2: Traditional stable, separation (flocculation), farm use liquid fraction and transport and application of solid fraction (30 km) (203 ha)

Scenario 3: Separation in stable and screw press farm use liquid fraction and transport and application of solid fraction (30 km). (203 ha)

The case farm is a pig farm which would like to expand from 250 LU to 500 LU or 18,000 finishing pigs per year. The crop rotation is barley, oilseed rape, wheat (1 year) and wheat (2 year). The N application follows the Danish N-norms, which is a legal requirement for clay soil (Danish Plante Direktorat, 2009). The average N application is 155 kg N per ha.

Table 1. Separation values used (% of the total share in the liquid fraction)

	Decanter (1	Flocculation (2	Source separation and screwpres (3
Amount (tonnes)	91	80-90	45
Total N	73	60-70	47
NH4-N	85	85-95	
Total P	(25) 40	1-50	57
Total K	90	80	42
Dry matter	30	8-36	79
Utilisation of N i fraction	85	85	80
Effective N:P index		6-7	

Source:
1) Landscenteret (2009)
2) Staring (2002) and Al-2
3) Peter Kai (2010).

Loss of N in the stable is 11% and loss in storage is 2% for slurry and liquid fraction, but 28% for the solid fraction (with cover). (Hansen et al, 2008). The utilisation of N in the field is based on trials. The amount applied on the field is the same for all systems.

The storage cost is an average based on Jacobsen et al. (2002). The storage cost is 17.0 DKK / tonne for slurry and 18.4 DKK/tonne for the two factions together (Jacobsen et al. , 2002). Larger storage is cheaper than small, but in this case, the costs per tonne are kept the same. The application costs are lower for slurry with hose than the solid fraction, and the liquid fraction is injected into the soil. The solid fraction is a little more expensive than slurry in terms of application. It is assumed that the spreading of animal manure costs around 13 DKK per tonne. The application costs are higher in the east than in the western part of the country, but this is an average figure (see Jacobsen et al., 2002).

The aim is to ensure that there is no P-surplus on the farm. The farm area before the expansion is 203 ha. The minimum when expanding the farm is 357 ha (area with harmony), but in that case there will be a small P-surplus. With 403 ha all the slurry can be applied on the field without no P-surplus. The question is whether to buy or rent another 200 ha, transport 4.230 tonne of slurry or invest in separation technology and export the solid fraction. The fertiliser purchase is based on price of N,P and K of 5, 9 and 2,5 DKK per kg. The utilisation of animal manure is described in the appendix A. In case the area is higher than 203 ha it is assumed that this land is rented and the farmer gets full value for the slurry applied to this area, but he does in this analysis not pay for the mineral fertiliser put on that area.

Table 2. Scenario 0a: Baseline – Traditional handling (203 ha, limited P surplus)

	Tonnes	Nitrogen purchase (Kg N)	Costs (DKK per tonne)	Total costs (DKK)
Amount ab stable	8,280			
Amount ab storage	8,460		17	143,820
Application on field	8,460		13	112,518
Mineral fertiliser (N)		11197		57,986
Transport of slurry	3,649		1	3.649
Sold slurry	3,649		38	- 137,222
Total costs			**21**	**180,751**
Costs per pig			**10**	

Note: The slurry for the area which exceeds 203 ha (154 ha) is transported 1 km and sold at full value. 100 DKK = 24.75 NZ $ = 13.4 €
Source: Own calculations

In case the additional land of 200 ha has to be rented paying an additional price of 1.500 DKK/ha / year on top of the production value, this would increase the costs by 300.000 DKK per year. The total costs would increase the costs by 36 DKK per tonne.

3.2. Decanter option

With respect to decanter centrifuge, the cost per tonne is smaller when large quantities are processed. The findings show that the cost on a farm with 500 LU is 15 DDK per tonne for a stationery unit or 136,780 DKK per year (including investment and maintenance). The mobile unit costs 267, 534 DKK per year with a capacity of 50.000 tonnes per year which gives a total cost of 5 DKK per tonne. However, such a capacity requires co-operation and that is sometimes difficult to get to work although there are economic incentives. This would require that the separator works 3.000 hours a year or 9 hours a day. Even though more farms share the decanter this should be possible.

The cost of application of the solid fraction is included as it is assumed to be applied on a field 30 km away. If it is only transport to a biogas plant (and not incorporated) the costs would be reduced by 18,000 DKK. The figures are summarized in table 4.

3.3. Flocculation

The flocculation approach is based on addition of polymers to the slurry. This makes the phosphor to coagulate. Approximately 0.2-0.3 litre of polymer is added per tonne slurry. The outcome of the flocculation can be varied more than with a decanter and the amount of P in the liquid fraction can be varied from 1 to 50% of total P (Hjorth et al., 2010). With a production of 8,500 tonne per year, the company AL-2 suggest that a model 2.1 will cover the requirements. The machine takes 3 tonnes per hour and has then to run 3,000 hours a year or 8 hours a day. However, most farmers will probably select the larger model 3.6M as the additional costs are limited.

Table 3. Costs related to flocculation from AL-2 (DKK

	Model 2.1	Model 2.1	Model 3.6	Model 3.6	Model 3.6
Amount	8.280	8.280	8.280	8.280	8.280
Press screw	No	Yes	No	Yes	Mobil
Investment in base	475.000	475.000	510.000	508.000	
Invest in screw press		225,000		225,000	
Container/ building	125,000	125,000	150,000	150,000	1,300,000
Total investment	**600,000**	**825,000**	**660,000**	**885,000**	**1,300,000**
Yearly costs					
Building etc. (10 år, 4%)	74,000	102,000	81,400	109,000	160,300
Variable costs	66,000	66,000	83,000	83,000	83,000
Labour (150 DKK/hrs) (1/2 dag)	27,000	27,000	9,100	9,100	30,000
Total costs / yr.	**167,000**	**195,000**	**174,000**	**201,100**	**273,300**
Costs (kr./tons) 8.280 tonnes	**20**	**24**	**21**	**24**	**33**
Costs with 15,000 tonnes.	**-----**	**-----**	**12**	**13**	**18**

Note: In other analyses the labour requirement is smaller than stated above. This with other adjustments, reduce the costs for the mobile unit to 200,000 DKK per year or 25 DKK/tonne in case of 8,280 tonne and model 3.6.
Source : AL-2 (2010) and own calculations.

The variable costs are polymer, water and electricity (0,7 kWh) and a service agreement on the equipment. The variable costs are 8-10 DKK per tonne. By using more or less polymer, the content of the products can be controlled. The last model is mobile and has sold a lot, but the idea of several farmers using it does not always work. Instead it has been owned by the biogas company. The company (AL2) has delivered about 30 of this type to farmers.

The actual N-utilisation is 85%, but it can be higher. The solid N can be utilised at 45-50%. With respect to P, the flocculation technique can deliver a wider range than the other technologies. For the nutrient balance to be covered 100% the share between effective N:P has to be around 155 N : 22 P or 7:1. Another index is the separation index which shows how much nutrient is removed (Hjorth et al., 2010).

For this farm, the costs of separation and screw press will be around 25 DKK per tonne. Again splitting the use between two farms and increasing the volume would reduce the costs to 18 DKK per tonne, but it is not always possible. With the mobile solution, the total costs are reduced to 60 DKK per tonnes or 28 DKK per finishing pig. The analysis indicates that flocculation is the most flexible, also in term of being able to fulfil the nutrient requirement. It is possible to apply the fractions so purchase of mineral fertiliser is not needed. This would reduce the cost by 20,000 DKK per year.

3.4. Source separation in the stable followed by screw press

The idea behind this technology is to carry out the separation in the stable and so the output from the stable is a liquid and a solid fraction. The solid fraction is then channelled through a press screw. The liquid part from this process is joined with the liquid part from the stable so that only two products come out of the process, namely a solid fraction from the screw press and a combined liquid product from stable and screw press. Compared to the other separation techniques, this technique does not take as much P away in the solid fraction.

A stable with source separation increases the total investment by 11% or 108.000 kr. for a stable which can produce 18,000 finishing pigs a year (Høj, 2009). In relation to the total yearly amount of slurry of 8,280 tonnes ab stable, this increases the costs by 13 DKK per tonne slurry which is processed. No additional costs related to energy use in the stable are included. On top of that comes the cost for the press screw, which is 27,200 DKK annually. The total cost, including 2% maintenance, is therefore 142,300 DKK per year. It is assumed that the utilisation of the liquid fraction is a little lower than the others and so it is set at 80% and with a higher loss in the stable this system has to lowest N value on the field (56%).

4. Results

The analysis shows that separation can be a valuable alternative to transport of slurry if the transport distance is 30 km or more, but the cheapest option is to distribute the slurry near the farm on your own fields. In livestock intensive areas renting a larger area to spread the slurry might cost 1,500 DKK/ha on top of the crop return and this increases the costs by 36 DKK per tonne to 57 DKK per tonne (see table 4).

The analysis show that decanter separation is the cheapest option as the separation costs are lower than for the other technologies (flocculation and source separation). In order to achieve this low cost per tonne, a mobile decanter has been chosen. If a stationary decanter is the only option, the costs per tonne will increase the separation costs from 5 to 15 DKK per tonne, increasing the total costs to 56 DKK per tonne. The costs are then similar to the costs of flocculation and increased transport. With the separation technologies the solid fraction can be transported a long distance without increasing the costs dramatically, as an increase from 30 to 50 km only increases the costs by 1 DKK per tonne. In case the receiver paid for the application this would also reduce costs by 13 DKK per tonne.

Source separation comes out as the most expensive option, not because of the separation costs, but because a larger amount is in the solid fraction and so the transport costs are somewhat higher. The costs here are more sensitive to transport distance. The separation and application costs are similar to the costs when using flocculation (mobile system). The advantage of renting / buying land as opposed to slurry agreements and separation and export of solid fraction is that you keep the full value of the nutrients. In case the solid fraction was sold at full value, separation technologies would be more profitable for the husbandry farmer. Although the value of the solid fraction is between 70-110,000 DKK, it assumed that the farmer receiving this will not pay anything based on current practice.

As mentioned, burning the solid fraction might be an option if the farmer is located near a large plant which can burn the solid fraction. This would only reduce the application costs and the transport would still have to be paid by the farmer and the fraction would not have any sales value (although it would generate heat). With respect to biogas, the farmer could export the solid fraction to an biogas plant, but it is assumed that the plant will not pay for this fraction. At one of the newest biogas plants in Denmark, a combination of farm separation and separation at the biogas plant is used. The analysis here indicates that using flocculation is the best in terms of providing full nutrient coverage with the liquid fraction.

Table 4. Economic results of the scenarios

Name	Scenario 0a Baseline - full value	Scenario 0b Baseline-transport	Scenario 1b Mobile-decanter	Scenario 2 Floccula-tion	Scenario 3 Source separation
Area (ha)	203	203	203	203	203
Transport distance (km)	1	30	30	30	30
P-surplus (kg P/ha)	3	0	0	0	0
Excess K	No	No	Yes	Yes	No
Eff. N:P in liquid fraction	4,0	4,0	8,4	7,7	5,8
Eff. Kg N/tonne	5.6	5.6	10.5 / 4.8	14.8/4.1	5.2 / 4.9
Kg P/tonne	1,1	1,1	6,5 / 0,5	6,5 / 0,5	1,7 / 0,7
Value solid fraction (DKK/tonne)	38	38	90	103	36
Economics (1000 DKK) :					
Storage costs	144	144	149	149	149
Separation costs	0	0	124	149	149
Application of liquid / slurry	119	113	142	142	98
Application of solid fraction	0	0	13	13	50
Transport of solid /slurry	0	128	25	25	94
Mineral fertiliser	58	75	14	26	57
Value of slurry / solid fraction	137	0	0	0	0
Total costs	**181**	**459**	**384**	**503**	**598**
Cost per tonne (DKK/tonne)	**21**	**54**	**46**	**61**	**72**
Cost per pig (DKK / pig)	**10**	**26**	**21**	**28**	**33**

Note: (solid fraction/liquid fraction)
Source: Own calculations

As shown in this analysis, the key parameters are how much you have to pay for buying land or slurry agreements and how far the slurry / solid fraction has to be transported and how much the farmer receiving is willing to pay? The conclusions are in line with what analysis made by The Danish Advisory Centre have shown namely: When farmers are faced with either: invest in separation, make a slurry agreement, rent land or buy more land the conclusion is that renting land is often the cheapest followed by slurry agreements and separation. Buying land comes out as the most expensive option.

5. Conclusion

The conclusion is that it is not profitable to invest in separation technologies unless the farm is situated in very livestock intensive area where it is difficult to get rid of the slurry. In general, the separation gives an additional cost which is difficult to justify unless the alternative transport distance is high or land prices are high. The analysis show that it is important to look at the entire chain as the separation technologies have a higher loss of N in storage and application costs are higher. The analysis shows that regulation, lower livestock numbers and changes in feeding has made separation less favourable over time. The future for separation seems to be in relation to future biogas plants.

The economics are very much dependant on the neighbouring farms' attitude to slurry and other fractions. The farm exporting will often lose the value of the slurry / solid fraction, but might also have to apply it on the other farm paying the application costs. This will benefit arable farmers. It is concluded that burning the solid fraction would be economically on large plants.

References

AL-2 (2010). Information sheet about separation. http://www.al-2.dk/

Anonymous (2010). Bekendtgørelse om husdyrhold og arealkrav mv. Nr. 947 fra 2006 and Bekendtgørelse af lov om landbrugsejendomme from 2010. https://www.retsinformation.dk/Forms/R0710.aspx?id=8750

Birkmose , T. and Zinck, A. M (2008). Status på afbrændning af husdyrgødning i Danmark – Juni 2008. Notat fra Landscenteret og Dansk Landbrug.

Brower, F.; Hellegers,P., Hoogeveen, M. and Luesink, H. (1999). Managing nitrogen pollution from intensive livestock production in the EU. Report 2.99.04. LEI, The Hauge.

Burton, C.J. (1997) Manure Management – Treatment Strategies for Sustainable Agriculture. Silsoe Research Institute, Silsoe, UK.

Danish Plant Directorate (2009). Gødningsnormer 2009-2010. Plantedirektoratet.

Dubgaard, A.; Nissen, C.J. Jespersen, H.; Gylling, M.; Jacobsen, B.H.; Jensen, J.D.; Hjort-Gregersen, K. Kejser, A.T. og Helt-Hansen, Julie. (2010). Økonomiske analyser for landbruget af en omkostningseffektiv klimastrategi. Rapport for Fødevareministeriet.

FVM (2005). Rapport fra arbejdsgruppen om afbrænding af fraktioner af husdyrgødning. Rapport udarbejdet for Fødevareministeriet.

Frandsen, T.Q. (2010). Metanudbytter af fiber fraktion fra gylleseperation. Notat. Videncenter for Landbrug.

Hansen, M.N., Sommer, S.G., Hutchings, N.J. and Sørensen, P. (2008). Emissionfaktorer til beregning af ammoniakfordampning ved lagring og udbringning af husdyrgødning. DJF Husdyrbrug no. 84. Det Jordbrugsvidenskablige Fakultet, Århus Universitet.

Hansen, M.N., Kristensen, J.K. and Kristensen, E.F. (2009). Forbrænding af fiberfraktionen fra separeret husdyrgødning. Info notat. AgroTech and DJF, University of Aarhus.

Hjorth, M.; Christensen, K.V., Christensen, M.L. and Sommer, S.G. (2010).Solid-liquid separation of animal slurry in theory and practice, A review. Agron. Sustain. Dev., 30, 153-180.

Hjorth-Gregersen, K. og Christensen, J. (2005). Afbrænding af fiberfraktion fra separeret gylle – Drifts- og samfundsøkonomiske analyser. Notat. Fødevareøkonomisk Institut.

Hjorth-Gregersen, K. (2009). Udbygning af biogasanlæg i Danmark – incitamenter – barrierer – anbefalinger.

Høj, P. (2009). Investering i kildesepareringsstald ct. Traditionel slagtesvinstald. Notat fra Svend Aage Christiansen A/S.

Jacobsen, B.H.; Sørensen, C.G. og Hansen, J.F. (2002a). Håndtering af husdyrgødning – en teknisk og økonomisk systemanalyse. Rapport nr. 138. Danish Research Institute of Food Economics (English summary).

Jacobsen, B.H.; Hjorth-Gregersen; Sørensen, C.G. and Hansen, J.F. (2002b). Separation af gylle – en teknisk-økonomisk systemanalyse. Report no. 142. Danish Research Institute of Food Economics. (English summary).

Jacobsen, B.H. and Hjorth-Gregersen, K. (2003). An economic and environmental analysis of slurry separation. Paper for the 14th IFMA conference in Perth, Australia.

Jacobsen, B.H. (2010). Reducing ammonia emission in Europe – Costs, Regulation and targets with focus on Denmark. Paper for the 18th IFMA conference in Christchurch, New Zealand.

Jensen, P.N. (2010). Status for miljøeffekten af miljøregulering og anden arealregulering. Notat. NERI, Aarhus University.

Jensen, T.K. (2009). Biogas til nettet. Projektrapport. Dansk Gasteknisk Center.

Jørgensen, K. and Jensen, L. S. (2010). Fibre fra gylleseperation – hvor stor er forskellen i deres kvalitet og hvordan anvendes de optimalt? I indlæg ved Plantekongres 2010, pp. 372-373.

Kai, P. (2010). Description of fractions from Source Separation. Note from GYLLESEP.

Kemira Miljø (2009). Gyllesseperation – helt enkelt. Notat om separation.

Landscenteret og KU (2007). Status over anvendelse af gylleseparation i Danmark. Notat fra Landscenteret og Det Biovidenskabelige Fakultet.

Landscenteret (2006). Biogas og gylleseparation – en god kombination. Notat. Dansk landbrugsrådgivning, Landscenteret.

Landscenteret (2009). Program til beregning af harmoni. http://www.landbrugsinfo.dk/Tvaerfaglige-emner/Gylleseparering/Sider/Beregn_harmoni_og_oekonomi_ved_gyllesepa.aspx

Maabjerg BioEnergy (2005). Miljømæssige, energimæssige og økonomiske konsekvenser af Maabjerg Bioenergi. Sammenfatning.Rapport. http://www.maabjerg-bioenergy.dk/

Miljøstyrelsen (MST) (2009a). Fodring. http://www.mst.dk/NR/rdonlyres/091AB3EB-6EB1-4808-AF75-F091721DFD57/0/Udkast_Svin_fodring_fosfor.pdf

Miljøstyrelsen (MST)(2009b). Overdækning af fiberfraktionen fra separeret gylle. BAT blad. http://www.mst.dk/NR/rdonlyres/A17F76D8-10E9-4305-A5C1-E961B5E359A9/0/Udkast_overd%C3%A6kningaffiberfraktioner.pdf

Miljøstyrelsen (MST) (2009c). Præcisering af lovgrundlaget og afklaring af en række fortolkningsspørgsmål vedr. forbrænding og forarbejdning af husdyrgødning. Notat-Miljøstyrelsen.

Miljøstyrelsen (MST) (2010). Separation af gylle med decanter centrifuge http://www.mst.dk/NR/rdonlyres/D167C805-F3FD-471F-9FC4-6158653426CE/0/Udkast_gylleseparering_dekantercentrifuge.pdf

Morsø Bioenergi (2009). http://www.biogasdk.dk/down/semdec07/Morsoe-Bioenergi.pdf

Møller, H.B. (2009). Hvad er status og udfordringen for forsuringsteknologien i relation til biogasproduktion. Indlæg ved Workshop om klimaeffeckt og teknologier til håndtering og behandling af husdyrgødning. DJF, Århus Universitet.

Møller, H.B. (2002). Status gylleseparering – muligheder og erfaringer. Bilag til Emnedag om teknik i landbruget 2002. Landbrugets Rådgivningscenter.

Møller, H.B., Lund, I. and Sommer, S.G. (2000). Solid-liquid separation of livestock slurry: efficiency and cost. Journal of Bioresource Technology, 74, (2000), 223-229.

Nielsen, L.H.; Hjort-Gergersen, K.; Thygesen, P. and Christensen, J. (2002). Samfundsøkonomiske analyser af biogasanlæg. Report no. 136. Danish Research Institute of Food Economics. (English summary)

Petersen, J. and Sørensen, P. (2008). Loss of nitrogen and carbon during storage of the fibrous fraction of separated pig slurry and influence on nitrogen availability. Journal of Agricultural Science, 146, 430-413.

Petersen, J. and Sørensen, P. (2007). Fiberfraktion fra gylleseparation – Tab af kulstof og kvælstof under lagering. Grøn Viden, Husdyr nr. 48, Det Joprdbrugsvidenskablige Fakultet, Århus.

Schou, J.S.; Gyldenkærne, S., Grant, R., Elmegaard, N., Palmgren, E. and Levin, G. (2006) Miljøkonsekvenser ved afbrænding af husdyrgødning med sigte på energiudnyttelse - Scenarieanalyse for et udvalgt opland. *Faglig rapport fra DMU, nr. 575*

Statistics Denmark (2010). Landbrug 2009. Danmarks Statistik.

Staring (2002). Gyllebehandlingsanlæg – NH_4^+ fra Staring Maskinfabrik A/S.

Sommer, S.G. and Møller, H.B. (2009). Gylle til energi og gødning. Notat fra Videncenter for Husdyrgødnings- og Biomasseteknologi.

Sørensen, C.G. and Møller, H.B. (2006). Operational and Economic modelling and optimization of mobile Slurry Separation. Applied Engineering in Agriculture, Vol. 22, 2, 185-193.

Appendix 1

Table A1. Case farm with 250 LU finishing pigs (18,000) and 8,460 tonne of slurry

Scenario	0	1	2	4
Stable	Traditional	Traditional	Traditional	Source separation
Separation technique	None	Decanter (mobil)	Flocculation (mobil)	Screw press
Storage	Storage with lit (not solid)	Storage with lit and cover on solid fraction	Storage with lit and cover on solid fraction	Storage with lit and cover on solid fraction
Field	Slurry	Liquid fraction	Liquid fraction	Liquid fraction
Export		Solid fraction	Solid fraction	Solid fraction
Area on farm	357 / 203	203	203	203
Transport distance (slurry/ solid fraction) (km)	30	30	30	30

Table A2. N –balance for the four systems (liquid/solid) (8,460 tonne)

	Baseline	**Decanter**	**Flocculation**	**Source separation**
Ab animal	54.360	54.360	54.360	54.360
Loss in stable	-5.870 (-10,8%)	-5.870 (-10,8%)	-5.870 (-10,8%)	-5.870 (-10,8%)
Ab stable	48.489	48.489	48.489	48.489
Loss in storage	-970 (-2%)	-4.121 (-2% / -28%)	-5.382 (-2% / -28%)	-6.895 (-2% / -28%)
Ab storage	47.520	44.368	43,107	41.594
Loss at application	-11.880 (-25%)	-10.146 (-15/-55%)	-9,339 (-10/-50%)	-11.162 (-15/45%)
Field effect (ab animal left)	**35.640 (66%)**	**34.221 (63%)**	**33,908 (62%)**	**30,432 (56%)**

Source: Hansen et al. (2008). The solid fraction is covered when stored.
In Jacobsen et al. (2002) the figure 30% was used. There are some uncertainties regarding the exact emissions for the different fractions as well as the field effect.

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Table A3. Content of nutrients in slurry on case farm (357 ha, 1,4 LU/ha)

	Ab stable	Ab storage	On field	Effective application (per ha)	Crop requirement	Mineral fertiliser (per ha)
Total amount (tonne)	8,280	8,460	8,460	24		
Total N	54,360	47,520	35,640	100	155	55
Total P	9,000	9,000	9,000	25	22	-3
Total K	23,580	23,580	23,580	66	70	4
Dry mater %	7,8	6,6				

Note: Requirement are based on Danish N-requirements (Plantedirektotatet, 2010).
In case the application is higher (e.g. 30 tonne per ha) the P surplus will increase on those fields, but the K application need will be fulfilled.

Table A4. Content in slurry / solid fraction (%) (pigs)

Scenario	0	1	3	4
Name	**Baseline**	**Decanter**	**Flocculation**	**Source separation**
Share (%)	100	10	10	38
Total N	100	25	35	47
Total P	100	60	55	59
Total K	100	10	10	40
Dry matter %	6,6	32	30	30
N-loss during storage (%)	2	28	28	28
Storage costs (DKK/tonne)	17	18	18	18
Utillisation of N in manure (%)	75	45	50	50
Effective value (DKK/tonnes)	38	135	103	36
Application cost (DKK/tonne)	13	18	18	18
Transport cost (DKK/tonnes)	30	30	30	30
Methane (Nm3/tonnes)	10-20	60-70	70-85	45-65

Source: Jacobsen et al. , 2002 and Hansen et al. (2008)
Note: There are some uncertainties regarding the methane production per tonne.