Baltic Slurry Acidification

Economic analysis of using of slurry acidification technologies in the BSR region

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1. Summary

The economic aspects have a crucial role for the farmer’s decision to choose one of acidification technologies (SAT) or some other solution to minimise ammonia emission from slurry. The calculation models are composed within the project to compare different solutions. Excel applications are built on bases of these models. Present report gives overview about data and methods used in analysis models. The calculation results are presented for every country participating in Baltic Slurry Acidification project. The report includes chapter about overall summary and conclusions of economic analyses and gives recommendations to improve cost-benefit of slurry acidification.

Slurry Acidification Technologies (SAT) decrease ammonia (NH_3) emissions by 49–64%. Reduced emissions mean that farmers save nitrogen (N) in slurry. Without SATs, farmers lose N from the slurry through NH_3 volatilization: 8–30% from pig or cattle house, 10–25% from open storage and 40–50% from non-tilled fields. In-house SAT has impact on N loss from ex-animal, in-pit SAT has impact on N loss from ex-house, in-storage and in-field SATs on ex-storage slurry, resulting the decrease of mineral N-fertiliser.

One litre of sulphuric acid contains 0.56 kg sulphur (S) and consequently 1.5–2.5 kg of S is applied with a ton of acidified slurry. It decreases cost of mineral S-fertiliser.

The investment to acidification system depends on which SAT is in use. However highest is the acid cost. Additionally should be taken into the account that by use of acidified slurry can be some rise of liming cost.

The results show cost-benefit of SATs by bigger slurry amounts compared to disc-harrowing <12 h after band-application of non-acidified slurry. The smallest minimum slurry amount was 1,100 m^3 yearly in Sweden by in-storage acidification of pig slurry.

All SATs have cost- benefit by pig slurry in all countries by bigger slurry amounts. The SATs have cost- benefit by cattle slurry in some countries.

However, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system in the farm. The farm savings do not always cover cost of acidification, so society must take some of the burden as a compensation for reduced ammonia emissions.

2. Introduction

The aim of this report is to increase knowledge concerning the environmental and economic impacts of slurry acidification technologies (SATs) in order to help build end-user confidence in SATs and to help justify the risks involved with investing in these innovative technologies. Environmental impact studies of SATs implementation are critical for highlighting the potential that existing innovative techniques have for improving manure fertilizer value, decreasing nitrogen loss from agriculture and helping countries meet strict ammonia emission reduction targets. **Financial studies of SAT implementation are critical for providing end-users with the tools necessary to make their own calculations and estimates on the feasibility and potential profitability of Implementing SATs.** The economic analysis of SAT implementation that combines both the environmental and financial analysis will be a key tool the project will provide to authorities and policy makers for raising their capacity concerning the value of supporting SAT implementation in relation to other measures for meeting the ammonia emission reduction targetsObjective

The aim of this report is to increase knowledge concerning the environmental and economic impacts of slurry acidification technologies (SATs) in order to help build end-user confidence in SATs and to help justify the risks involved with investing in these innovative technologies.

3. Collecting of data and calculation methods

3.1. Data collecting methods

Data about SATs technical parameters and prices directly fom SAT producers

a. In-Farm acidification - JH Agro A/S

b. In-storage acidification – HARSØ and Ørum Smeden

c. In filed acidification - BioCover

Country based data were collected by project partners((see Appendix 3).

3.2. In-house acidification – cattle farms

3.2.1. Investment costs in cattle farms

In the cattle barn the mixing tank is not used, the slurry is acidified in slurry channel. Acidification in one spot means that it's possible to add the acid somewhere in the stable or a ring channel.

The slurry-collecting channel in barn should be big enough and should contain so much slurry, that the mixer can work and is able to store and treat with acid the amount of one or more scraper interval. Important is ,that the amount of acidified slurry is big enough to lower the pH in the new slurry from the cows. Also important is that during the mixing no air is pumped into the slurry. The channel should be designed with a cycle, so that mixer can work efficiently. A wall in the middle is necessary.

The quality of the cattle slurry has to be such that it can be stirred in the stable so that the acid can be mixed properly. If the slurry is separated then it will be more susceptible to stir around and may need a less acid.

By the information from JH Agro A/S (e-mail contact with Ken Hyldgaard, Kurt West and Holger Schulz) is possible to establish their acidification system for all sizes of cattle farms. Generally there is one acidification spot, if there are up to 500 cows, and two, if there are more than 500 cows. Acid addition in spot No. 2 is coupled to the system and it is possible to add more acid addition spots.

An approximately price for a system with one spot is 87,000 €. An approximately price for Acid addition spot No. 2 is 10,000 €. Maximum distance from spot No. 1 is 25 m.

The system costs are relatively various. If the tank is small (for a small barn) and the installation is very easy , the price is low (50,000 €). However, if there are some more details needed, so the price is higher. Small acid tank means that the tank is then 4,000 liter and for roughly 150 cows , without mixer.

Example 1: For 800 cows has been installed a double system (because of two barns) in Germany and the price for a double tank system is around 110,000 €. That system can handle two acids, because the slurry is pumped to a biogas plant.

Example 2: In Germany are installed two acids system for 2 barns . 400 cows and 400 young cows. There we are going to use sulfur acid and acetic acid. There are two big tanks included 15 m^3. This system will cost 150,000 € without mixers. Acetic acid is also known as ethanoic acid $C_2H_4O_2$ and is for example produced in a biogas plant during the methanation.

If there are scrapers in cattle stable and the slurry is not recirculating in cross channels then there is no possibility to acidfy the slurry in the barn. In that case is suggestable to use in-house acidification system in slurry pumping pit (or better in extra processing tank) between stable and storage. If that pit is big enough is possible to treat slurry for roughly 1,000 cows.

If a farmer wants to buy a acidification plant for cattle farm, then he have to build concrete foundation for acid tank with power and water connections. The rest is with the plant and will be installed when the plant is coming.

Spot No. 1 contains: (Report 2.1):

1) acid tank;
2) pH-meter, pumps, valves, flow meters, control panel which provides complete automation of the acidification and slurry pumping process ;

3) emergency shower and eye wash nearby in case of an accident.

These are items what are included to the 87,000 €. Additionally is required mixer in slurry channel to ensure homogeneity of slurry. The acid resistant stainless steel mixer can be delivered by JH Agro optionally.

The acid tank should have a concrete foundation with an integrated collision protection system. The dimensions of the process tank, mixer and pumps are individually dimensioned for the specific situation. The loading place for acid truck.

The concrete foundation can made from normal water-resistant concrete. The acid tank is around 40 ton when it is full, so the concrete base should be dimensioned in connection to the soil. In the economic calculations is taken into account that the foundation is 0.2 m thick with two layers of steel, 10 m long and 4 m wide.

There’re different sizes of the tank possible. The biggest tank is around 7 m long and 2.5 m wide. Recommended is to build the concrete foundation a little bit bigger e.g. 10 x 4 m. The concrete plate should have an overflow (a plastic pipe with Ø ca 100 mm) for the acid at the end, it lets to flow acid into the slurry channel.

For the protection for the tank, the iron bars in 0.8 m high are recommended to install on the edge (0,2 x 0.2 m) of concrete plate. Just to take care of damages from a truck or tractor.

Figure 1. Sulphuric acid tank for in-house acidification (JH Agro)

For the water connection can be calculated with the normal pressure from waterworks (4 bar) and size of tube for emergency shower is 32 mm. The pipe heater should be used to avoid freezing of water if outside temperature is below zero.

By planning the electricity supply for acidification plant should be calculated with 240 V and 2 x 16 A. It means 2 cables with wires 3 x 1.5. No special EL installations. Power to pumps and slurry mixer is mounted as if there was no slurry acidification.

For distance control is internet connection needed and therefore data cable should be installed.

The acidfication tank can be installed close to the barn wall and maximum distance between slurry acidification point (slurry channel or pumping pit) and acid tank can be 25 m.

A acid tank foundation building cost in Estonia 14,624 € without VAT. The calcultion was ordered from Eelarvestusgrupp OÜ, a company making daily building cost calculations for building companies in Estonia. The overview about cost items is shown in Appendix 1.

Spot No. 2 additions mean there is possibility to add acid into two ring channels or two stables.

3.2.2. Calculation of depreciation, cattle farm

By the information from JH Agro there has not replaced the in-house acidification systems since the first system which works more than 10 years.

Thus, 20 year lifetime is used in calculation of depreciation of in-farm acidification system depreciation.

30 year lifetime is used in calculation of concrete base, power connection, water connection and loading place for acid truck. KTBL suggests to use 30 year lifetime for long lasting building parts (KTBL 2016 pg 517).

To calculate depreciation cost per cubic meter of slurry, the investment costs are divided by lifetimes of system parts and annual slurry production of the barn.

3.2.3. Maintainance cost, cattle farm

To calculate maintenance cost per cubic meter of slurry, the annual maintenance cost is divided by the annual slurry production of the barn.

JH Agro offers a service contract for acidification system maintenance, so that proved is the optimal work of the system. The price is about 1,500 € per year and acidification spot for in-house SAT in cattle farm

3.2.4. Cost of bank loan interest, cattle farm

Interest is calculated as an average from the life-span of a investment:

$$c_i = \frac{a_p i_p H\left(1 - \frac{O_f}{100}\right)}{2 \cdot 100 T_a W} ,$$

where a_p - length of loan period, years;

i_p - rate of interest, % year^{-1} and
O_f - rate of self-financing, % from loan sum.

The value “2” in formula is used to calculate the average remaining value of the investment.

Table 1. Bank loan interest rates, in different BSR countries

Country	**Bank loan interest rate, %**
Estonia	3
Latvia	4–5
Russia	5–10, depends on: - machinery and equipment; - farm type; - subsidy
Sweden	3–4
Lithuania	4
Germany	1.5–3.5
Finland	2
Poland	3–5
Belarus	9.5
Denmark	3–4

Thank bank loan interest cost is calculated same way for all SAT and production types.

3.2.5. Insurance cost, cattle farm

The cost of insurance for in-house acidification system with concrete base (101,000 eur) was asked from 7 Estonian insurance companies. Insurance against fire, vandalism and storm. The range of offers was 114–369 eur per year. Own risk 300 1000 eur. For economic calculations was chosen 149 eur, because by the cheapest offer was condition that the device should be in observing area of guard.

Thus, for flexibility of calculations was calculated that the insurance rate is 149 / 101,000 * 100 ≈ 0,15% of price of new system.

Thank insurance cost is calculated same way for all SAT and production types.

3.2.6. Energy cost, cattle farm

To calculate energy cost per cubic meter of slurry, the annual energy cost is divided by the annual slurry production of the barn

In-house SAT for cattle barn uses electrical energy to drive small acid pump and controlling system. By the information from JH Agro is the power consumption of acidification system so low that energy cost is not needed to calculate.

The mixer in slurry channel of the cattle barn takes some more energy, but this mixing is made also in the case if the slurry acidification system is not installed.

3.2.7. Safety costs in cattle farm

Extra acid-proof work clothes are not required if in-house SAT is used. Workers don't have any contact with acid.

3.2.8. Labour cost, cattle farm

There is no need for active work on the in-house system, it works automatically. The operator should take care of the system regularly, check every day the pH and look after the system at the mixer to be sure that there are no noticeable problems. One hour per week is approximate time consumption for these actions (personal contact with Holger Schulz, JH Agro).

The labour cost is calculated with formula

$$C_l = \frac{365 p t_d}{Q}$$

where C_l –labour cost € m^{-3}; p is operator's hourly personal cost with taxes € h^{-1}; t_d is daily work time connected to acidification system h day^{-1}; Q is annual slurry amount produced in the barn.

Table 2. Labour personal costs with taxes.

Country	Labour personal cost with taxes € h^{-1}
Estonia	7.4
Latvia	5
Russia	3,6
Sweden	25
Lithuania	4.1
Germany	27.5
Finland	16
Poland	3.8
Belarus	2.4
Denmark	25

Additionally, the vacation cost should be calculated. It means that if worker has 28-day vacation per year (generally in Estonia) then the personal cost with taxes should be multiplied with 1,083.

3.3. In -house system, pig farms

3.3.1. Investment costs in pig farms

Housing systems for intensive pig production are generally designed around slurry manure handling and indoor confinement year-round and the buildings are insulated and heated, although some solid manure systems still exist. The defecating behaviour of pigs differs from cattle in that they have separate places for resting and defecating. Most pig housing systems have either fully or partially slatted floors with either a deep pit or shallow manure channel underneath. Deep litter pens can also be used in conjunction with partially slatted floors over the manure collection channels. Production of finishing pigs and weaners generally occurs in smaller groups in pens, although large pens are used in some occasions. Breeding pigs can be kept individually or in groups (except when farrowing).

Source: Baltic Manure. 2013.

In-house SAT for pig barn contains (WP 2.1, BSA 2018):

1) acid tank;
2) processing tank with mixer;
3) pH-meter, pumps, valves, flow meters, control panel which provides complete automation of the acidification and slurry pumping process ;
4) acid pipes from acidification tank to acidfication point;
5) emergency shower and eye wash nearby in case of an accident.

The acid tank should have a concrete foundation with an integrated collision protection system. The process tank is made of concrete and mixers are made from acid resistant stainless steel. The dimensions of the process tank, mixer and pumps are individually dimensioned for the specific situation.

If the in-house acidification system is used, then in the pig barns slurry is sluiced out and pumped back again. The area of a cellar below slatted floor in a pig farm (fatteners) is limited, it is not bigger than 1,500 m² and one valve is per cellar. At present one JH Agro acidification system can run up to 8, in some cases 12 valves at the facility, depending on the total number of place units. There can be as much cellars as the farm needs, JH Agro can handle them with their system (personal contact with Holger Schultz, JH Agro).

JH Agro has systems for stables which produce 32,000 finishers per year and new projects which produce up to 42,000 finishers per year.

> The price of a system with 6 valves is about 200,000 €, plus process tank, mixer and acid tank base.
>
> The price of acid tank base and communications is same as by the cattle farm (see 3.2.2 and Appendix 1).

The volume of the acid tank is suggestable to choose by the volume of acid truck plus some extra space for residual amount of acid before refilling of acid tank plus some airspace above acid level after refilling.

The volume of process tank must be same as amount of slurry coming weekly from cellar plus 50 cm space for foaming plus rest in the bottom, so in total additional 1,5 m (JH Agro). For the price of processing tank is required to:

1) calculate amount of slurry produced per m^2 of pen floor;
2) calculate amount of slurry produced per slurry cellar and week;
3) calculate required size of processing tank;
4) ask price of this size round concrete tank from some company building slurry tanks.

<u>Calculation of amount of slurry produced per squaremeter of pen floor</u>

Although there are national differences, housing with fully or partly slatted flooring (typically on concrete slats with 17 mm slot spacing) with a pen floor area of 0.7 m^2 at the end of the finishing period predominates within the EU.

Partly slatted floors are mostly used in countries such as the Netherlands, the Czech Republic and Denmark. In Germany fully slatted floors prevail and in Spain both types of floor are used with the proportion of slatted to solid floor being 60 : 40. In Belgium, fully slatted floors are prevalent in old housing or in new houses equipped with a chemical scrubbing system. In the UK, straw bedding is common.

Source: BREF 2017 , page 83.

In Finland and Sweden, housing systems with fully slatted floors are not allowed due to animal welfare regulations. See also 'Cross-media effects' in Section 4.7.1.1 for fully slatted floors.

Source: BREF 2017 , page 373.

In economic calculations is calculated with 3,2 batches of finishers per year and every finisher produces 0,5 t slurry. It means that 3,2 x 0,5 = 1,6 t a^{-1} slurry is produced per animal place yearly. If one animal place is 0,7 m^2, then 1.6 / 0.7 = 2.29 m^3 m^{-2} a^{-1} slurry is produced.

The formula to calculate the amount of slurry produced per one m^2 of floor of pen is:

$$Q_{floor} = \frac{n_{batch} Q_{pig}}{S_{animal}}$$

where Q_{floor} is amount of slurry produced per one m^2 of floor and year, m^3 m^{-2} a^{-1}; n_{batch} is number of fattener batches produced yearly per one animal place; S_{animal} is area of one animal place, m^2 animal^{-1}.

<u>Calculation of amount of slurry produced per slurry cellar and week</u>

If proportion of slatted to solid floor in pens is 60 : 40 and slatted floor area is 1500 m^2, then total area of pens connected to one cellar is 1,500 * 100 / 60 = 2,500 m^2. The annual slurry production from this area is 2500 * 2,29 = 5,725 t a^{-1}.

The slurry cellar valve is opened once per week, it means that 5725/(365/7)=110 m^3 week^{-1} of slurry is pumped from slurry cellar to the processing tank. 365/7 in number of weeks in one year.

The formula to calculate the amount of slurry pumped from slurry cellar to the processing tank once per week is:

$$Q_{cellar} = \frac{7 Q_{floor} S_{cellar}}{3.65 r_{slatted}}$$

where Q_{cellar} is amount of slurry pumped from slurry cellar to the processing tank once per week, m^3 $week^{-1}$; S_{cellar} is area of slatted floor above one slurry cellar, m^2; $r_{slatted}$ is proportion of slatted to whole floor in pens, %.

<u>Calculation of required size of processing tank</u>

The volume of process tank must be same as amount of slurry coming weekly from cellar plus 50 cm space for foaming plus rest in the bottom, so in total additional 1,5 m (JH Agro). In Denmark the heights of processing tanks are between 3–5 m. If to calculate 4 m total inside height of tank, then tank inside diameter is sqrt(110 / (4 – 1.5) / π) * 2=7.5 m.

The formula to calculate diameter of processing tank is:

$$D_{proc} = 2\sqrt{\frac{Q_{cellar}}{\pi(h_w - 1.5)}}$$

where D_{proc} is inside diameter of processing tank, m; h_w is height of processing tank wall inside, m.

Figure 2. Scheme of in-house SAT in pig barn. (JH Agro)

<u>Price of processing tank</u>

A tank made from 10 concrete elements, each 4 m high, has diameter 7.4 m and volume 160 m^3. This tank costs 30,000 eur (including digging, base, concrete casting, concrete walls and concrete cover) in Estonia (Acontank).

Figure 3. Acid tank (left) and processing tank near pig barn. (JH Agro)

Slurry mixer and pump, power and price

Inside the processing tank is required a stationary mixer which is able to to mix the slurry and acid in tank in total and for sure. The power of the mixer depends on size of the process tank.

The mixer is not included to the price of acidification system. However, JH Agro offers LJM mixer from 7.5 kW up to 15 kW. The cost for those mixers are around 5,000 € up to 7,500 €. For a 160 m^3 tank containing 110 m^3 of slurry a 10 kW mixer is suggested by JH Agro. The interpolated price of 10 kW mixer is about 5,850 eur.

By the calculations of a Estonian company selling slurry mixers and pumps for storages, the 7.5 kW mixer with stand, mast and cable clamber costs 4,700 eur. The company advisor infromed that this mixer is powerful enough for these conditions.

A 11 kW centrifugal pump between process tank and storage tank costs 6,000 eur with sump and base wihth electical heating system.

JH Agro recommends also to separate slurry regularly, when the sluicing to the process tank begins, it makes pumping easier and reduces acid consumption.

3.3.2. Maintenance cost, pig farm

To calculate maintenance cost per cubic meter of slurry, the annual maintenance cost is divided by the annual slurry production of the barn.

JH Agro offers a service contract for acidification system maintenance, so that proved is the optimal work of the system. The price is about 500 € per year and valve of slurry cellar if in-house SAT in pig farm is used.

By the mixer in processing tank every second year the oil have to be changed, about 10 litre, around 50 € in total.

3.3.3. Energy cost, pig farm

There is additional energy cost in pig farm to pump the slurry to the processing tank and mix the slurry with acid in the tank.

The duration of mixing process depends on the slurry ph and volume. One acidification cycle lasts 20–45 min per cellar. In sectioned pig houses, individual sections will be treated this way sequentially. 45 min is used in present economic analyses.

It is always important to mix the slurry absolute homogenous. The mixer size depends on the size of the process tank. JH Agro offers up to 15 kW but e.g . for 160 m^3 tank a 10 kW is optimal.

The electricity consumption of mixer is calculated with formula:

$$E = \frac{b n_{valves} P_{mixer} t_{mixer} W}{e}$$

where E is yearly electricity consumption of mixer, kWh a^{-1}; n_{valves} is number of slurry cellars or valves; P_{mixer} is power of mixer engine, kW; t_{mixer} is mixing time of slurry coming from one slurry cellar per week, h $week^{-1}$; W is number of weeks in one year, week a^{-1} (the value of W is 365/7); b is work load of electric motor, % of nominal power; e is energy use efficiency of electric motor, %.

In calculations is b = 50% and e = 90%.

The cost of the annual electricity consumed by the mixer is calculated with formula

$$C_{e,mixer} = \frac{p_e E}{Q}$$

where $C_{e,mixer}$ is annual energy cost connected to the mixer, € m^{-3}; p_e is cost of electricity, € kWh^{-1}.

Similar way is calculated electricity consumption and annual eenergy cost of slurry pump, moving slurry out from processing tank.

3.3.4. Safety costs in pig farm

Extra acid-proof work clothes are not required if in-house SAT is used. Workers don't have any contact with acid.

3.3.5. Labour cost, pig farm

The labour cost is calculated same way like in cattle farm, see chapter 3.2.8.

3.4. In-pit acidification system

For Sweden, the in-house tehnology is calculated with presumption that acidification starts in slurry pumping pit in cattle and pig barn both. It means that there is not taken inot account ammonia emission nor decrease of emission in barn. The calculations base on slurry N_{tot} content ex-housing. By Lena Rodhe the ex-housing and ex-storage data in Sweden are close.

By the information from JH Agro presenter Holger Schulz is the price of acidification system is same for in-barn and in-pit acidification both. However, 5,000 € for addinional mixer should be calculated in pumping pit, to mix slurry and acid during in-pit acidification. The slurry pump is controlled by acidification system to adjust slurry level in pit.

SAT producer suggests, that some acidified slurry should be in the pit, so that the new slurry from the barn flows into the prepared slurry. However, the process is more or less continious. After start of use of acidification system, the pit contains always some acidified slurry. The pit has to be so big that the amount of new slurry is only a small part (lower than 5%) of the complete volume of the pit.

The other costs for in-pit SAT are same as by in-house SAT.

3.5. Safety costs

Sulphuric acid is classified as a substance with pH < 2 that is highly corrosive to skin and eyes. Sulphuric acid vapours can also be harmful to the respiratory tract and mucous membranes. The correct personal protective equipment is therefore imperative when sulphuric acid is handled.

Appropriate personal protective equipment is (WP 2.5 BSA 2018)

- acid-resistant safety boots/shoes;
- fully covering acid-resistant protective suit (e.g. in butyl rubber or neoprene), which may be disposable;
- protective gloves (in fluorocarbon rubber 0.4 mm thick or butyl rubber 0.5 mm thick) certified in accordance with EN 374-2003 (fabric, leather, natural rubber, polychloroprene/chloroprene rubber and nitrile rubber are unsuitable materials);
- protective eyewear or a full-face mask at concentrations above the occupational exposure limits (with gas filter E, release of sulphur dioxide, or an aerosol mask with filter P3, mist formation) in accordance with SS-EN 141.

Table 3. Prices and the annual demand of personal protective equipment items for in storage acidification

Personal protective equipment item	Amount for one year, pcs	Price, € pcs^{-1}	Cost, € yr^{-1}
Boots	0.5	12.5	6.25
Protective suits	3	11	33
Protective cloves	3	30.1	90.3
Protective mask	0.2	87.5	17.5
Filters for mask	3	14.5	43.5
Total cost			160.55

3.6. In-storage SAT costs

In-storage SATs acidify slurry in the storage. The most commonly practiced in- in Denmark is slurry acidification just before the slurry is spread and therefore storage acidification there are no benefits of the acidification during the main storage period. There are two manufacturers that make systems for in-storage acidification and both are modified slurry mixers that add acid to the slurry during the mixing process. (WP 2.1, BSA 2018)

Prices of in-storage acidification devices (WP 3.1, BSA 2018)

HARSØ (pump-mixer):

€ 75,000, including

€ 10,000 for the acidification equipment and

€ 65,000 for the slurry pump

Ørum Smeden (propeller mixer):

€ 14,000 for the acidification equipment +

€ 25,000 for the GDM7500 slurry mixer or

(60–230 kW tractors)

€ 38,000 for the GDM8600 slurry mixer

(110–300 kW tractors)

Maintenance cost

Until now there is no knowledge of significant maintenance costs. The components used are of high quality and not yet replaced any in the last 6 years where the system has been on the market.

Expepcted is that probably the senso should be replaced after years of use. (The sensor requires a little attention and it´s important that the protective cover is mounted after use so that it does not dry out). Worst case, a new sensor will amount to approx 400 EUR. (Personal contact with Henrik Nielsen, Ørum-Smeden).

In the economic calculations is calculated with 60 eur maintenance costs per year.

Mixing performance

If the acid is mixed into slurry before spreading to the field then there is no need to calculate fuel cost, because slurry anyway have to be agitated and homogenised before spreading.

If there is longer period between mixing of acid and spreading to the field, then the homogenising should be made two times and fuel consumption of slurry mixing during acidification should be calculate as cost of acidification.

Ørum Smeden gives data for power need of mixers. This is 150 kW in average for smaller mixer.

The acid pumping performance is 100 litres of acid per minute. The mixing time during acidification is calculated by this value in the formula:

$$t_{mixer,s} = \frac{a_a Q}{60 q_a}$$

where $t_{mixer,s}$ is mixing time during acidification, h; q_a is acid pump performance, l min^{-1}.

Impact on slurry storage capacity.

When lowering the pH in slurry during acidification, bicarbonate components in slurry are converted to carbon dioxide which bubbles to the surface and produces foam. Because of the foaming, there must be free space in the storage to assure the foaming does not spill over during the treatment. A height of 0.5 to 1 m is commonly recommended. 1 m is used in present economic analyses.

In the KTBL 2016/2017 page 500 are given slurry storage costs € m^{-3} for different storage capacities. The trendline, built by these values, has formula:

$$y = -0.257 \ln(x) + 3.364 \qquad R^2 = 0.9975.$$

where x is torage capacity and y is cost of storage, € yr^{-1}.

Labour demand and cost

Calculated is that during the acidification is involved one assisting worker from farm.

Personal protection

The delvery of acid in IBC tanks offers logistical flexibility during acidification, but puts also greater responsibility on the farmer/operator for maintaining safety. Full body safety gear is necessary during operation. See section "Safety costs".

N loss reduction after in-storage acidification.

The 55% is the reduction factor what is use in Denmark, following advice from agricultural consultants (Personal contact with Henrik Nielsen, Ørum-Smeden).

3.7. In-field SAT costs

In-field SAT is used to acidify slurry on the field during application. (WP 2.1 BSA 2018)

Prices of in-field acidification devices

BioCover SyreN:

List price is 65,000 Euro ex works + fitting (normally app. 5,000 Euro).

If the tractor has no ISO Bus terminal, then additional 3,000 € should be calculated for that.

BioCover prototypes are still running after 10 years and with no view to stopping. For depreciation is calculated with 20 years life time.

Kyndestoft acidification system:

List price: 40,000 €

Maintenance cost

Biocover Syren has service kit containing pH sensor, calibration fluids, gloves and fee for data transmission (if fitted) = 900 Euro pr. year. No other cost is known, but experience says that yearly maintenance is app. 1,400 Euro

If farm has own refillable IBC tanks for acid, then in some countries like Sweden, is required to replace utilised IBC tanks after certain time span with new tanks. In

Sweden the life span of IBC tanks is 2.5 years. The acid delivery company keeps track of the age of the IBC tanks and will not refill tanks that are damaged or have passed their expiration date for safety reasons.

The cost of IBC tanks per cubicmeter of slurry is calculated with formula:

$$k_{IBC} = \frac{a_a n_{IBC} p_{IBC}}{Q_a T_{IBC}}$$

where k_{IBC} is cost of IBC tanks per cubicmeter of slurry, € m^{-3}; n_{IBC} is number of IBC tanks utilised for acid in farm; p_{IBC} is price of an IBC tank, €; Q_a is annual demand of acid in farm, l a^{-1}; T_{IBC} is life span of a IBC tank, years.

Table 4. Prices of 1000 l plastic IBC tanks, in different BSR countries

Country	**1000 l plastic IBC tank prices € tank^{-1}**
Estonia	190
Latvia	190
Russia	145
Sweden	220
Lithuania	140
Germany	900 costs of one Varibox
Finland	210 . lower price if several are ordered (4–9 = 200 €, 10–15 = 185 €)
Poland	120
Belarus	61
Denmark	220

Labour costs

BioCover has experiences that changing of the IBC tank with 1,000 liter acid takes 4 min from tractor driver if full IBC tank is ready on field .

The labour cost of changing of IBC tank per cubicmeter of slurry is calculated with formula:

$$c_{l,IBC} = \frac{a_a p t_{IBC}}{60 V_{IBC}}$$

where $c_{l,IBC}$ is labour cost of changing of IBC tanks, € m-3; p is operators hourly personal cost with taxes, € h-1; t_{IBC} is time what is required to change an IBC tank, min $tank^{-1}$; V_{IBC} is volume of IBC tank, l $tank^{-1}$.

Storage cost of IBC tanks

The IBC tanks (filled with acid or are emptied after acidification) should be stored in safe place in farm to avoid damaging of tanks and also risks to persons, environment and properties.

The cost of storage of IBC tanks in farm per cubicmeter of slurry is calculated with formula

$$c_{s,IBC} = \frac{n_{IBC} p_{st} S_{IBC}}{Q}$$

where $c_{s,IBC}$ is cost of storage of IBC tanks in farm per cubicmeter of slurry, € m^{-3}; p_{st} is price of storage € m^{-2} a^{-1}; S_{IBC} is area required to store a IBC tank, m^2 $tank^{-1}$.

The KTBL 2016/2017 (pg 154) gives data for different type of storages. A storage hangar closed in all sides has annual cost 14.43 € m^{-2} a^{-1}.

Generally, the IBC tanks are stored and transported on wooden or plastic pallets that ensure easier loading of tanks. The standard size of IBC tank bottom and also pallet is 1,000 X 12,000 mm (Feraxo 2018). Thus, area required to store a IBC tank is 1.2 m^2. In the calculation is taken into the account that the IBC tanks with acid are stored in one layer.

Acid transportation to the field

The IBC tanks can be transported from storage to the field and back on front hitch of tractor which is working with slurry spreader and SyreN slurry acidification system.

If spreader is filling slurry tank by slurry storage itself and it locates near to the storage of the IBC tanks, then there is no need to calculate cost of transportation of the IBC tank from storage to the field. The transportation of the slurry and IBC tank to the field can be made by same drive.

If fields are further from slurry storage, then generally separate tank trucks are used to transport the slurry from storage to the field and spreader should drive from field away only to change IBC tank with acid.

In that case the cost of driving with spreader between field and storage should be calculated.

The cost of transportation of IBC container with spreader per cubicmeter of slurry is calculated with formula:

$$k_{IBC,spreader} = \frac{a_a d_{IBC} p_{spreader}}{v_{spreader} V_{IBC}}$$

where $k_{IBC,spreader}$ is cost of transportation of IBC container with spreader per cubicmeter of slurry, € m^{-3}; d_{IBC} is average distance between fields and IBC storage, km; $v_{spreader}$ is average velocity by transporting IBC tank with slurry spreader, km h^{-1}; $p_{spreader}$ is price of work hour of spreader, € h^{-1}.

Another possibility to transport IBC tanks between storage and field is to use separate transporting vehicle. It means that the IBC tanks should be loaded with fork loader from storage to the vehicle, transported to the field and then loaded from vehicle to the field side.

The cost of transportation of IBC container with separate vehicle is calculated with formula:

$$k_{IBC,vehicle} = \frac{a_a p_{vehicle}}{n_t V_{IBC}} \left(\frac{d_{IBC}}{v_{vehicle}} + \frac{t_l}{60} \right)$$

where $k_{IBC,vehicle}$ is cost of transportation of IBC container with spreader per cubicmeter of slurry, € m^{-3}; $p_{vehicle}$ is price of work hour of vehicle, € h^{-1}; t_l is loading and unloading time of IBC tanks, min; n_t is number of IBC tanks transported with one drive, pcs; $v_{vehicle}$is average velocity by transporting IBC tank with separate vehicle, km h^{-1}

The transportation with 15 m trailing hose spreader and 15 m^3 tank costs 80 € h^{-1}. If 10 t trailer and 65 kW tractor with loader and fork is used for transportation then hourly cost of machine is 33 € h^{-1}. Hourly costs include also fuel and labour costs. The costs are calculated by Raivo Vettik (ECRI).

In the calculations is chosen average driving speed for spreader 30 km h^{-1} and for vehicle 40 km h^{-1}. Loading and unloading time is 10 min if vehicle is used. If transportation is made with spreader then the cost of changing IBC tank is calculated in labour costs of spreader oprator already.

If fields are close to the IBC storage then it is cheaper to transport IBC tank with spreader. And in the case of longer distances is cheaper to use separate vehicle (Figure 4)

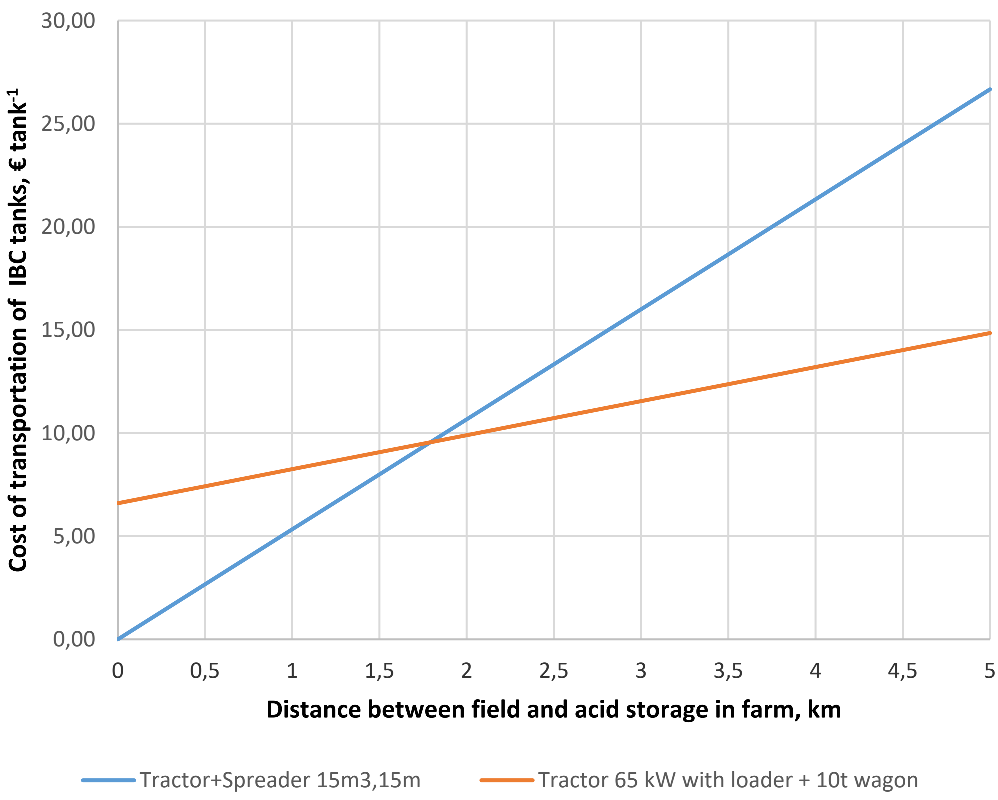

Figure 4. Cost of transportation IBC tanks, comparison in the case of different transportation machines.

The distance where transportation costs are equal, can be calculated with formula:

$$d_{IBC} = \frac{t_l}{120\left(\frac{p_{spreader}n_t}{v_{spreader}p_{vehicle}} - \frac{1}{v_{vehicle}}\right)}$$

The equal distance on Figure 4 is 1.8 km. It means, that if distance between field and IBC storage is longer than 1.8 km, then for transportation of IBC tanks is cheaper to use separate vehicle and not spreader.

Acid pump fuel consumption and cost

BioCover SyreN acid pump is driven by hydraulic engine. Acid pump oil need is 25 liter min^{-1} from hydraulic system. BioCover hasn't data about acid pump power consumption. The pressure in the hydraulic to the oil motor is variable as it depends on the dosage pump speed. It is a max 25 liter oil motor. Known is that when working stable, the pressure in the 1" acid dosage hose is about 3 bar. (Morten Toft).

Thus, the power need of acid pump can be estimated by calculations. Hydraulic power is a calculated of pressure and flow (Roeber et al. in Computers and Electronics in Agriculture 127 (2016)):

$$P_h = \frac{p_a f_a}{c_a 600}$$

where P_h is consumption of the hydraulic power of acid pump, kW; p_a is pressure of acid, bar; f_a is flow of acid, l min^{-1} and c_a – multiplied efficiencies of acid pump, hydraulic motor and hydraulic engine.

The acid flow can be calculated by formula:

$$f_a = \frac{a_a a_{ha} b v}{600}$$

where b is working width of slurry spreader, m; v is working speed of spreader, km h^{-1}. 600 is result of converting of units.

For example, if acid consumption a_a = 2 l m^{-3}; slurry amount a_{ha} = 30 m^3 ha^{-1}; spreader width b = 18 m and working speed v = 8 km h^{-1}, then acid flow is 14.4 l min^{-1}.

There are no data about acid pump efficiency. However, oil pump efficiency is by literature typically in range 0.85–0.92 depending on type of pump (Casey, 2011).

The acid pump is driven by oil motor and oil motor is driven by oil pump. In the calculations 0.9 as efficiency value is used for each of them: acid pump, hydraulic motor and hydraulic pump. Thus total efficiency for system is $c_a = 0.9^3 = 0.73$

Thus, in the previous example, the power demand for pumping of acid is 0,1 kW.

Fuel consumption per hour is calculated with formula

$$p_{f,l} = q P_h \rho_f$$

where $p_{f,l}$ is fuel consumption l h^{-1}; q is specific fuel consumption, kg kWh^{-1} (typically 0.21 kg kWh^{-1}), m; ρ_f is diesel fuel density kg l^{-1} (0.861 kg l^{-1}).

Fuel cost per cubicmeter of slurry is calculated with formula:

$$k_f = \frac{10 p_{f,l} w_f}{a_{ha} b v}$$

where k_f is fuel cost, l m^{-3}; w_f is fuel price € l^{-1}.

Table 5. Fuel costs in BSR region.

Country	**Diesel fuel cost € l^{-1}**	**Comment**
Estonia	0.594	Includes transport
Latvia	0.63	Transport 1 € km^{-1}
Russia	0.36	Includes transport
Sweden	0.95	Transport 0.015 € km^{-1} (3,000 l trucks)
Lithuania	0.524	Includes transport
Germany	0.9–1,2	That is the range so far in Germany
Finland	0.77	Includes transport
Poland	0.98 0.98 – 0.14 = 0.84	Farmer can reduce the diesel fuel price (costs) by obtaining partially excise tax refund i.e. 20.5 EUR/ha/year. If diesel demand 150 l/ha/year, then minus 0.14 €/l .
Belarus	0.53	0,35 € km^{-1} (truck transport)
Denmark	0.95	Transport 0.015 € km^{-1} (3,000 l trucks)

Personal protection

Personal protection items like acid-proof gloves, face protection mask and spray for eye rinse are included to the SyreN start kit and the price if SyreN. Gloves are also included to annual service kit (see maintenance costs). Thus, extra costs for personal protection are not calculated.

N loss reduction after in-field acidification.

N-loss during spreading if slurry is not acidified is shown in Table 13.

VERA verification statement says that SyreN has ammonia emission reduction efficiency at 49 % when applied on cattle slurry (VERA 2012.)

3.8. Acid cost

Estonia

Sulphuric acid prices in Estonia are collected from three chemicals resellers: Ingle AS, Kemimet International OÜ and Keemiakaubandus. They all deliver it also with tank truck, 24 t portion. The prices in the table (7) is with delivery to Jõgeva, (Estonia). Acid source is Belarus. Acid concentration is 94% and density is 1.831 g cm^{-3}. The date of price is 14.11.2017. 2 hours of unloading time is included to the price. If diver has to wait with unloading, then waiting time costs 50 € h^{-1}. The delivery is made 1–2 weeks after order. (Source: Ingle AS, Kemimet International OÜ and Keemiakaubandus)

Russia

The prices collected from big companies in Moscow and Leningrad regions are:

1) technical sulphuric acid – 0.077 eur l^{-1};
2) improved sulphuric acid – 0.093 eur l^{-1}.

These prices are without VAT and without transportation cost.

Specification of these acids is in the table (6). Technical acid is used for production of mineral fertilizers and should be good enough to add to organic fertilizer.

Table 6. Specifications of technical and improved sulphuric acid (GOST 2184-2013) sold in Moscow and Leningrad regions (Russia). (http://www.eurochemgroup.com/en/product/sulphuric-acid/)

Main specifications	Norm	
	Improved sulfuric acid	**Commercial (technical) sulfuric acid, 1st grade**
Mass fraction of sulphuric monohydrate (H2SO4), %	92.5–94.0	Not less than 92.5
Mass fraction of free sulphuric anhydride (SO3), %, not less than	–	–
Mass fraction of ferrum (Fe), %, not more than	0.006	0.02
Mass fraction of precipitation after baking, %, not more than	0.02	0.05
Mass fraction of nitric oxides (N2O3), %, not more than	0.00005	Not rated
Mass fraction of nitro compounds, %, not more than	Not rated	Not rated
Mass fraction of arsenic (As), %, not more than	0.00008	Not rated
Mass fraction of chlorides (Cl), %, not more than	0.0001	Not rated
Mass fraction of plumbum (Pb), %, not more than	0.001	Not rated

The acid is produced in Leningrad region as well. There are at least two producers: "EuroChem" and "Metachem", both part of big mineral fertilizer producers.

It is possible to order acid with a truck (24 t). Transportation to farms has never happened. If to calculate with average transport distance to a farm 100 km and 1 eur km^{-1}, then the price would be 142 eur t^{-1}.
Transport of IBC tank is cheaper – 0.7 eur km^{-1}. Thus, if to calculate with average transport distance to a farm 100 km and, then the price would be 112 eur t^{-1}.

Lithuania

Acid price 0,240 € l^{-1}. 1000 l IBC tank (240 euro for 1,000 l). Acid transportation cost to the farm 1.20 € km^{-1}. Acid concentration, 96%. 131 + 12 = 143 € t^{-1} with transport, if 10 tonne is transported 100 km.

Sweden

Acid price 0.62 € l^{-1} if acid is bought with 1,000 l IBC tank. If acid is bought with 25 t tank, then the price is 0.265 € l^{-1}. Acid transportation cost to the farm is included in the price. Acid concentration is 98%.

Finland

The acid price is 0.97 € l^{-1} if acid is transported with IBC containers. In addition, transport cost 70 € t^{-1}. Thus, the acid price is with transport is 1.1 € l^{-1} or 602 € t^{-1}.

Table 7. Sulphuric acid prices in Baltic sea region. Prices are without VAT.

Country	**Acid price, € t^{-1}**	**Acid concent-ration**	**Transport to the farm € km^{-1}**	**Comments**
Estonia	118–127	94–98%	Included to acid price.	24 t portion.
Estonia	135	94–98%	Included to acid price.	10–12 t portion.
Estonia	150	94–98%	Included to acid price..	1,000 l, in IBC.
Latvia	150	98%	1	1,000 l, in IBC.
Russia	42	94–96%	0,7	1,000 l, in IBC.
Russia	42	94–96%	1	24 t.
Sweden	149	98%	Included to acid price.	0.265 € l^{-1}, 25 t portion
Sweden	339	98%	Included to acid price.	0.62 € l^{-1}, 1,000 l IBC
Lithuania	131 143 with transport, 10 tonne and 100 km	96%	1,2	240 € m^{-3}, 1,000 l IBC
Germany	262	96%	0,9	0,48 € l^{-1}, 1000 l IBC
Finland	602 with transport	93%	70 € t^{-1}	0.97 € l^{-1} 1,300 kg container ≈ 710 l = 689 €
Poland	273	95%	0.72	0.5 € l^{-1}, 25 l canister
Belarus	101	98%	0.35	1,000 l, in IBC. 0,35 € km^{-1} transport
Belarus	30	94%	1.25	Bulk. 1.25 € km^{-1} transport, 30 m^3.
Denmark	120–128		Included to acid price.	Delivery by truck
Denmark	136–157		Included to acid price.	IBC tanks, but price excluded the price of the IBC tanks

The overview about acid producers is given in Appendix 2 “Information about sulphuric acid producing plants in Baltic Sea region”.

The consumption of sulphuric acid has over several years been followed by SEGES in connection with field trials with slurry acidification – see table 8.

Table 8. Average consumption of sulphuric acid, litres per tonne of slurry / digestate (after Nørregaard Hansen and Knudsen, 2017).

	In-house	In-storage	In-field
Cattle slurry	4.5	3.6	3
Pig slurry	3.5	3.0	2.6
Digestate	N/A	-	7.9

3.9. Liming

3.9.1. Soil pH and liming

By USDA (1999, all this paragraph) , soil pH is an excellent chemical indicator of soil quality. Farmers can improve the soil quality of acid soils by liming to adjust pH to the levels needed by the crop to be grown. Benefits of liming include increased nutrient availability, improved soil structure, and increased rates of infiltration.

Soil pH is a measure of the number of hydrogen ions in the soil solution. However, the actual concentration of hydrogen ions in the soil solution is actually quite small. For example, a soil with a pH of 4.0 has a hydrogen ion concentration in the soil water of just 0.0001 moles per liter. (One mole is equal to the number of hydrogen atoms in 1 gram of hydrogen). Since it is difficult to work with numbers like this, pH is expressed as the negative logarithm of the hydrogen ion concentration, which results in the familiar scale of pH ranging from 0–14. Therefore, pH = 4.0 = - log (0.0001). Because the pH scale employs the use of logarithms, each whole number change (for example from 5.0 to 4.0) represents a 10-fold increase in the concentration of H+ ions. Note that as the amount of hydrogen ions increases, pH decreases. A pH of 7 will have a hydrogen ion concentration 100 times less than a soil with pH of 5.

Soil pH is also:

• an indicator for potential plant growth and
• an indicator of required lime, but does not tell how much lime is needed.

As rainfall increases, bases (positively charged ions) like calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^{+}), and sodium (Na^{+}) are leached out of the soil and are replaced by hydrogen (H^{+}). Short-term pH changes are due to natural processes and management such as:

• rainfall;
• plants removing bases (like Ca^{2+});

• acid forming fertilizers such as ammonia nitrate (NH_4NO_3);
• organic acids from plants during decomposition;
• CO_2 from root respiration and microbial respiration.

Active acidity (or soil-water pH) is due to the presence of H^+ ions in the soil solution. Active acidity will indicate a need for lime. *Potential acidity* (or buffer pH) is the amount of Al^{3+} and H^+ ions that are adsorbed on soil particles (negatively charged cation exchange sites) and can be desorbed from these exchange sites to the soil solution (buffering the soil) when liming materials are added. It is the potential acidity that determines the amounts of agricultural limestone to neutralize soil acidity. As potential acidity increases, a larger amount of lime is required to raise pH by a given amount. As cation exchange capacity increases (higher clay and organic matter), the amount of liming material needed to change soil pH also increases. Soils with a low cation exchange capacity may only require 1 ton of agricultural limestone to change a pH from 4.5 to 6.5; whereas, a soil with a higher CEC may require 2 tons of agricultural lime to make the same change.

Liming will provide the following benefits:

• reduces the possibility of Mn^{2+} and Al^{3+} toxicity;
• improves microbial activity;
• improves physical condition (better structure);
• improves symbiotic nitrogen fixation by legumes;
• improves palatability of forages;
• provides an inexpensive source for Ca^{2+} and Mg^{2+} when these nutrients are deficient at lower pH;
• improves nutrient availability (availability of P and Mo increases as pH increases at 6.0–7.0, however, other micronutrients availability increases as pH decreases).

3.9.2. Fertilisers and soil acidity

By McLaughlin (2013, all this paragraph), soil acidification is a widespread natural phenomenon in regions with medium to high rainfall, and agricultural production systems can accelerate soil acidification processes through perturbation of the natural cycles of nitrogen (N), phosphorus (P) and sulphur (S) in soil, through removal of agricultural produce from the land, and through addition of fertilizers and soil amendments that can either acidify soil or make it more alkaline.

Changes in soil pH may be advantageous or detrimental depending on the starting pH of the soil and the direction and speed of pH change – for example decreases in soil pH in alkaline soils may be advantageous for crop production due to benefits in terms of the availability of P and micronutrients e.g. zinc (Zn). On the other hand, decreases in soil pH for a highly acidic soil may be detrimental in terms of increasing crop susceptibility to toxicity induced by increased solubility of aluminium (Al) or manganese (Mn) as soil pH falls.

N-fertilisers

The form of N and the fate of N in the soil-plant system is probably the major driver of changes in soil pH in agricultural systems.

Ammonium-based fertilizers will acidify soil as they generate two H^+ ions for each ammonium molecule nitrified to nitrate. The extent of acidification depends on whether the nitrate produced from ammonium is leached or is taken up by plants. If nitrate is taken up by plants the net acidification per molecule of ammonium is halved compared to the scenario when nitrate is leached. This is due to the consumption of one H^+ ion (or excretion of OH^-) for each molecule of nitrate taken up – this is often observed as pH increases in the rhizosphere. Anhydrous ammonia and urea have a lower acidification potential compared to ammonium-based products as one H^+ ion is consumed in the conversion to ammonium. Nitrate-based fertilizers have no acidification potential and actually can increase soil pH as one H^+ ion is absorbed by the plant (or OH^- excreted) in the uptake of nitrate.

S-fertilisers

The form of S fertilizer added to soil can affect soil acidity, principally through the release of H^+ ions by the addition of elemental S (S_0) or thiosulfate ($S_2O_3^{2-}$, in ammonium thiosulfate - ATS) . However, the amounts of S added to soil and taken up by plants are generally small in comparison to N.

For each molecule of S_0 added to soil, two H^+ ions will be generated, and these can be balanced through plant uptake by either uptake of H^+ (same as excretion of OH^- ions) or the generation of OH^- (effectively organic anions) within the plant to form alkaline plant material ("ash alkalinity"). Where produce is removed (which is often the case in agricultural systems) net acidification of soil will occur if S_0 or ATS are used.

Table 9. Acidification potential for various N, P and S fertilizers expressed as kg lime equivalent per kg of N, P or S applied (McLaughlin, 2013)

Fertilizer	Acidification potential	
Nitrogen fertilizers	kg lime equivalent to neutralize acidity **per kg N**	
	If all nitrate leached	If all nitrate taken up
NO_3	0	-3.6
NH_4NO_3	3.6	0
Urea	3.6	0
Liquid NH_3	3.6	0
SoA	7.1	3.6
MAP (pH > 7.7)	10.7	7.1
MAP (pH < 6.7)	7.1	3.6
DAP (soil pH > 7.7)	7.1	3.6
DAP (soil pH < 6.7)	5.4	1.8
Phosphorus fertilizers	kg lime equivalent to neutralize acidity **per kg P**	
	Soil pH <6.7	Soil pH >7.7
SSP	0	1.6
TSP	0	1.6
MAP	1.6	3.2
DAP	1.6	3.2
PA	1.6	3.2
Sulfur fertilizers	kg lime equivalent to neutralize acidity **per kg S**	
SoA	0	
Elemental S	3.2	
ATS, (NH4)2S2O3	4.8/3.2 (nitrate taken up)	
Gypsum	0	

Severly acidifying are Sulfate of ammonia (21% N) and Mono-ammonium phosphate (MAP) (11.3% N).

These fertilisers are so acidifying that even if all the nitrogen is taken up by the plants, you need to apply around 4 kg of lime for every kg of nitrogen. If all the nitrogen is leached, you need to apply 7 kg of lime for every kg of nitrogen. On average, use 5.5 kg of lime for every kg of nitrogen.

Source: From the Soil Sense leaflet 2/92, Agdex 534, produced by Rebecca Lines-Kelly, formerly soils media officer, Wollongbar Agricultural Institute, for CaLM and NSW Agriculture, north coast region, under the National Landcare Program, August 1992.

https://www.dpi.nsw.gov.au/agriculture/soils/improvement/n-acidify

3.9.3. Liming prices

Table 10. Liming prices in Baltic sea region. Prices are without VAT.

Country	**Liming material price, € t^{-1}**	**Liming service € t^{-1}**	**Transport to the farm € t^{-1} km^{-1}**	**Lime handling costs in farm with own equipment, € t^{-1}**
Estonia		29.3 € t^{-1}		
Latvia	48.38	58 (if 100 km transp.)	0.062	3.3
Russia	8.5		0.2	2

Sweden		30		
Lithuania	130	175	Included to liming material price.	45
Germany	31		1.1 € km^{-1}	20–25 depending field-farm distance
Finland		42		
Poland	24	32	0.31–1.0	
Belarus	60	77	0.07	3
Denmark		30		

Estonia

Liming service price is 29,3 € t^{-1}, it contains liming material, transport to Jõgeva and spreading. Procduct is ENEFIX fly ash. Liming service with dolomite lime from Rakke lime producer - 16.7 € t^{-1} with 50 km transport.

Latvia

Product is dry dolomite flour, Ca 20.3%, Mg 10.9%, packed in big bags 1 tonne. Price of dry limestone flour with Ca 38.4% in big bags is 64.03 € t^{-1}. Raw dolomite sand - 6.5 € t^{-1} (without package). Transportation cost 0.062 € t^{-1} km^{-1}, with truck which has capacity over 10 tonnes. Service costs 0.089 € t^{-1} km^{-1}.
Lime handling costs in farm with own equipment 3.3 € t^{-1} (storage, loading, transport to the field, spreading or liming service cost).

Russia

Dolomitic lime in the bulk. Liming cost for 100 km distance is 30.5 eur t^{-1}.

Lithuania

Liming material price, 130 € t^{-1} with transportation. Lime handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), 45 € t^{-1}. Liming service cost which includes three previous costs, 175 € t^{-1}

Finland

Liming service cost includes liming material, transport to the farm and spreading.

Sweden

Liming service cost which includes liming material, delivery to farm and handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), is 30 € t^{-1}.

3.9.4. Liming cost

Addition of acid to slurry increases the need for lime because of a reaction between acid and soil calcium carbonate, which evaporates CO_2 and lowers the soil pH. The addition of 1 litre of sulfuric acid per ton of manure and applying 30 t ha^{-1} a^{-1} will require 75 kg agricultural lime (75% $CaCO_3$) a year, to offset acidification from the acid. An acid consumption of 4 l t^{-1} of slurry (common by storage acidification of pig manure, stable acidification often uses more acid) requires an annual lime need of 300 kg ha^{-1}. (SEGES report “Status, economy and consideration by acidification of slurry”.)

Thus, the lime demand is 2.5 kg per litre of sulphuric acid.

The cost of additional liming in the case of acidified slurry is calculated with formula

$$K_{l,a} = \frac{k_l a_l a_a}{1000}$$

where $K_{l,a}$ – cost of additional liming € m^{-3} of slurry if slurry is acidified; k_l – cost of liming € t^{-1} of lime, a_l – lime demand kg per litre of sulphuric acid; a_a – amount of acid used for acidification of one cubic meter of slurry kg m^{-3}.

If slurry is not acidified then the amount of N and S reaching to the plants is smaller compared to acidified slurry. The lack of these elements should be covered with use of the mineral NS fertilisers. In paragraph 3.8.2 were explained that the use of mineral NS fertilisers cause also the acidifying of soils. By the data in the table 8, if for example, a NS fertiliser SoA is used and all nitrate is leaching, then 7.1 kg lime equivalent should be used to neutralise acidity per kg N. And if all nitrate is taken up, then the lime amount should be 3.6 kg per kg of N. In the calculation models is presumed that nearly all nitrate is taken up by plants and lime amount is 4 kg per kg of N.

The cost of additional liming in the case of non-acidified slurry (and additional mineral fertiliser is used) is calculated with formula

$$K_{l,m} = \frac{k_l a_{l,N} m_N}{1000}$$

where $K_{l,m}$ – cost of additional liming € m^{-3} of slurry if slurry is not-acidified; k_l – cost of liming € t^{-1} of lime, $a_{l,N}$ – lime demand kg per kg of N given with mineral fertilisers; m_N – the amount of N saved by slurry acidification kg m^{-3} (see chapter 3.9).

3.10. N cost reduction

The main reason to acidify slurry is to decrease ammonia emission. It helps to increase the on amount of inorganic N which is available for plants. Thus, the need for mineral N fertiliser decreases. In the calculation is presumed that additional amount of N saved by decrease of NH_3 emission diminishes the expenses on same amount of mineral N.

The calculation of the reduction of mineral N cost by slurry acidification consists next steps:

1) calculation of N loss with ammonia if slurry is not acidified;
2) calculation of N loss with ammonia by use of some SAT, calculations are different for in-house, in-storage and in-field SATs;
3) calculation of N saved by use of SATs;
4) calculation of mineral N element price;
5) calculation of reduction of mineral N cost by slurry acidification.

<u>Calculation of N loss with ammonia if slurry is not acidified</u>

The sum of the NH_3-N loss in barn, storage and field is calculated with formula

$$L = L_b + L_s + L_f$$

where L – sum of NH_3-N losses in barn, storage and field kg m^{-3}; L_b – NH_3-N loss in barn kg m^{-3}; L_s – NH_3-N loss in storage kg m^{-3}; L_f – NH_3-N loss in field kg m^{-3}.

NH_3-N loss in barn is calculated with formula

$$L_b = a_{N_{tot}} \frac{k_b}{100}$$

where a_{Ntot} – amount of total nitrogen N_{tot} in slurry (ex-animal) kg m^{-3}, k_b– loss of NH_3-N in barn in the case of the non-acidified slurry % (Table 11).

NH_3-N loss in storage is calculated with formula

$$L_s = \frac{k_s}{100}\left(a_{N_{tot}} - L_b\right)$$

where k_s– loss of NH_3-N in storage in the case of the non-acidified slurry % (Table 12).

The average ammonia emission values in stable, storage and field depend among othres on weather conditions. Thus in countries with different climate, the values are different compared to the values in the tables 11, 12 and 13. Reccomendable is to use in calculations country based ammonia emission values.

Table 11. NH_3-N emissions in cattle barn by different slurry removing systems in Estonia (ENVIR 2016)

Animal group	Manure removal strategy	NH_3-N emission, % TN
Dairy cows	Loose housing, mobile manure removal 2…3 times per day, little bedding	8
	Loose housing, manure removal with scraper >3 times per day, little bedding	7.5
	Loose housing, slatted floor, little bedding	10
Pigs, fatteners	Fully slatted floor (concrete), vacuum system, cooling of slurry bottom layer	10
	Fully slatted floor (concrete), vacuum system, without bedding	14
	Fully slatted floor, slurry cellar, without bedding	30
	Partially slatted floor (concrete), convex bedding area, slurry channels, slurry flushing	15
	Partially slatted floor (concrete), vacuum system, without bedding	14

	Partially slatted floor (plastic or metal)), slurry removal - self flowing, without bedding	15
	Partially slatted floor (plastic or metal), vacuum system, without bedding	13
	Partially slatted floor, cooling of slurry surface layer	13
	Partially slatted floor, slurry channels with sloped walls	15
	Partially slatted floor (concrete), vacuum system, cooling of slurry bottom layer	9
	Partially slatted floor, scrapers, little bedding	12

In Finland and Sweden, housing systems with fully slatted floors are not allowed due to animal welfare regulations. See also 'Cross-media effects' in Section 4.7.1.1 for fully slatted floors.

Source: BAT 2017 , page 373.

Table 12. NH_3-N loss from artificially not covered slurry storages in Estonia (EULS 2013)

Cover	NH_3-N loss from storage, %	
	Tank	Lagoon
Uncovered	14	24
Natural crust	10	20

The data about ammonia emission reduction of artificial covers is shown in section 3.10.1.

NH_3-N loss in field is calculated with formula

$$L_f = \frac{k_f}{100}\left(a_{N_{tot}} - L_b - L_s\right)$$

where k_f– loss of NH_3-N in field in the case of the non-acidified slurry % (table 13).

The NH_3 emission values can be calculated for different technologies, slurry properties and weather conditions. The calculations are made with figures in the table13.

Table 13. NH_3 emissions by cattle slurry broadcast spreading if air temperature is 20°C, wind speed is 5 m s^{-1}, dry matter content is 8%, Ntot content is 3 kg m^{-3} and slurry amount is 30 m^3 ha^{-1} , wet soil (ALFAM).

Slurry spreading technology	Ammonia emission, %

Band spreading	40
Band spreading, incorporation < 12 h	30

<u>Calculation of N loss with ammonia by in-house acidification</u>

The sum of the NH_3-N loss in barn, storage and field for in-house acidified slurry is calculated with formula

$$L_{a,h} = L_{b,a} + L_{s,ah} + L_{f,ah}$$

where $L_{a,h}$ – sum of the NH_3-N loss in barn, storage and field for in-house acidified slurry kg m^{-3}; $L_{b,a}$ – NH_3-N loss in barn for acidified slurry kg m^{-3}; $L_{s,ah}$ – NH_3-N loss in storage for in-house acidified slurry kg m^{-3}; $L_{f,ah}$– NH_3-N loss in field for in-house acidified slurry kg m^{-3}.

NH_3-N loss in barn for acidified slurry is calculated with formula

$$L_{b,a} = \frac{L_b(100 - r_b)}{100}$$

where r_b - ammonia emission reduction in the barn in the case of slurry acidification %.

Ammonia emission reduction in stable by slurry acidification is (http://jhagro.com/faq-slurry-acidification/):

64% from pig barns (documented by VERA)
50% from cattle barns (documented by VERA).

The treatment reduces ammonia evaporation:

1. from the stable
2. during slurry storage
3. during application of slurry to fields

Source: JHAgro homepage, http://jhagro.com/jh_nh4_cattle/

NH_3-N loss in storage for in-house acidified slurry is calculated with formula

$$L_{s,ah} = \frac{k_s(100 - r_s)}{10000}\left(a_{N_{tot}} - L_{b,a}\right)$$

where r_s - ammonia emission reduction in the storage in the case of slurry acidification %.

Here have to be taken into account the storage period of acidified slurry. If slurry is acidified before storage like it is by in-house acidification, then the acidification impacts ammonia emission during storage.

NH_3-N loss in field for in-house acidified slurry is calculated with formula

$$L_{f,ah} = \frac{k_f(100 - r_f)}{10000}(a_{N_{tot}} - L_{b,a} - L_{s,ah})$$

where r_f - ammonia emission reduction in the field in the case of slurry acidification %.

Calculation of N loss with ammonia by in-storage acidification

The sum of the NH_3-N loss in barn, storage and field for in-storage acidified slurry is calculated with formula

$$L_{a,s} = L_b + L_{s,as} + L_{f,as}$$

where $L_{a,s}$– sum of the NH_3-N loss in barn, storage and field for in-storage acidified slurry kg m^{-3}; $L_{s,as}$– NH_3-N loss in storage for in-storage acidified slurry kg m^{-3}; $L_{f,as}$– NH_3-N loss in field for in-storage acidified slurry kg m^{-3}.

NH_3-N loss in storage for in-storage acidified slurry is calculated with formula

$$L_{s,as} = \frac{L_s(100 - r_s)}{100}$$

Here have to be taken into account the storage period of acidified slurry. How long was the slurry in storage without acidification, and how long with acidification.

NH_3-N loss in field for in-storage acidified slurry is calculated with formula

$$L_{f,as} = \frac{k_f(100 - r_f)}{10000}(a_{N_{tot}} - L_b - L_{s,as})$$

Calculation of N loss with ammonia by in-field acidification

The sum of the NH_3-N loss in barn, storage and field for in-field acidified slurry is calculated with formula

$$L_{a,f} = L_b + L_s + L_{f,af}$$

where $L_{a,f}$– sum of the NH_3-N loss in barn, storage and field for in-field acidified slurry kg m^{-3}; $L_{f,af}$– NH_3-N loss in field for in-field acidified slurry kg m^{-3}.

NH_3-N loss in field for in-field acidified slurry is calculated with formula

$$L_{f,af} = \frac{L_f(1 - r_f)}{100}$$

By the information from BioCover, if SyreN technology is used to make in-field acidification of slurry, then the ammonia emission reduction effect of 49% (VERA, 2012) and 40% (Environmental technology list, 2017) accordingly for cattle and pig slurry.

<u>Calculation of the amount of N saved by use of SATs</u>

The amount of N saved by slurry acidification is calculated with formulas

$$m_{N,h} = L - L_{a,h}$$

$$m_{N,s} = L - L_{a,s}$$

$$m_{N,f} = L - L_{a,f}$$

where $m_{N,b}$ – N weight saved by in-house slurry acidification kg m^{-3}; $m_{N,s}$ – N weight saved by in-storage slurry acidification kg m^{-3}; $m_{N,f}$ – N weight saved by in-field slurry acidification kg m^{-3}.

<u>Calculating mineral N in-field -cost</u>

In some mineral fertilisers like ammonium nitrate is the N the only nutrient element in fertiliser. Such kind of fertiliser is used to calculate N element price. All the costs (fertiliser cost, delivery to farm, and handling in farm) are taken into account, which have to be made to rise N content in field with help of the mineral fertiliser:

$$p_N = \frac{0{,}1\left(p_{f,N} + p_d + p_{N,h}\right)}{c_N}$$

where p_N– mineral N element cost € kg^{-1}; $p_{f,N}$– mineral N fertiliser price € t^{-1}; p_d– mineral fertiliser delivery cost , € t^{-1}; $p_{N,h}$– mineral N handling cost € t^{-1}; c_N–N content in N fertiliser, % (table 14).

If the fertiliser price doesn’t include the delivery from reseller to the farm, then the delivery cost is calculated with formula:

$$p_d = dp_{d,km}$$

where d – the transportation distance between reseller and the farm, km;, $p_{d,km}$– mineral N delivery cost per kilometre € t^{-1} km^{-1} (table 14).

Else the p_d value is zero.

Table 14. Mineral N- fertiliser prices, mineral N prices (100% N) prices and fertiliser handling costs in Baltic sea region. Prices are without VAT.

Country	Fertiliser	Price, with delivery € t^{-1}	Price of mineral N with delivery to 100 km € kg^{-1}	Fertiliser delivery[1)] € t^{-1} km^{-1}	Fertiliser handling[2)] € t^{-1}
Estonia	Ammonium nitrate N - 34%	249	0.72	Included[3)]	27.3
Latvia	Ammonium nitrate N - 34%	230	0.68	0.062	33.97
Russia	N-100%	523	0.523	0.2	20
Sweden	Ammonium nitrate N - 34%	240	0.7	0.13	50
Lithuania	Ammonium nitrate N - 34%	250	0.73	Included[3)]	35
Germany	CAN 27 % 13.12.2017	213	0.79	0.9 with	15–20,

				truck	depending on the field - farm distance
Finland	Urea Plus, 46% N	323	0.7	170 € t^{-1} regardless of the distance	50, taken from Swedish data
Poland	Ammonium nitrate N - 34%	250	0.73	0.31–0.6	27
Belarus	Urea, 46% N	219	0.48	0.07	30
Russia	Ammonium nitrate N - 34%	160-195	0.5	0.2	20
Denmark	Ammonium nitrate N - 34%	345	1	0.13	50

1)Fertiliser delivery cost to the farm, € t^{-1} km^{-1}

2)Mineral fertiliser handling costs in farm (storage, loading, transport to the field, spreading), € t^{-1}

3) Fertiliser delivery cost is included to the fertiliser price

Calculation of mineral N fertiliser handling cost

Table 15. Mineral fertiliser handling cost items and values in Estonia if 350 kg ha^{-1} is average fertiliser amount. Prices are without VAT.

Cost item	**Unit**	**Price**	**Comment**
Storage costs	€ t^{-1}	2.4	KTBL 16/17, pg154 (30 x 159). 14.43€ a^{-1} m^{-2}, 1.5 t m^{-2}, 3 months
Loading to the trailer	€ t^{-1}	0.47	1 t BigBag
Hauling to the field	€ t^{-2}	3.37	5 km from storage the field
Loading to the spreader	€ t^{-1}	0.47	1 t BigBag
Spreading hectare cost	€ ha^{-1}	7.2	By Raivo Vettik calculations
Need of physical fertiliser	kg ha^{-1}	350	Average, it depends on fertiliser properties and nutrient demand of crops.
Spreading cost	€ t^{-1}	20.6	
Sum of handling costs	**€ t^{-1}**	**27.3**	

If crops are fertilised with NS fertiliser, then the handling costs are divided by proportional content of element in fertiliser.

Thus, the N portion of handling costs is calculated with formula:

$$p_{N,h} = \frac{c_N p_h}{c_N + c_S}$$

where p_h– mineral N handling cost € t^{-1} (table 13); c_N–N content in NS fertiliser, % (table 18); c_S–S content in NS fertiliser, % (table 18).

Calculation of the reduction of mineral N cost by slurry acidification

$$r_N = m_N p_N,$$

where r_N – reduction of mineral N cost by slurry acidification € m^{-3}.

3.11. S cost reduction

Following nitrogen, phosphorus, and potassium, sulphur is an essential plant nutrient. It contributes to an increase in crop yields in three different ways: 1) it provides a direct nutritive value; 2) it provides indirect nutritive value as soil amendments, especially for calcareous and saline alkali soils; and 3) it improves the use efficiency of other essential plant nutrients, particularly nitrogen and phosphorus. Sulphur is necessary for plant growth and nutrition. (TSI 2018).

The suggestable N:S rate for oilseed rape and *Brassica rapa subsp. oleifera* (Biennial turnip rape) is 4–6:1 (the lighter is the soil texture, the narrower have to be the N:S), for cereals it is wider – 10–15:1 and grasslands 14–16:1. (Väetamise ABC, 2014)

Most crops remove 15 to 30 kg for sulphur per hectare (S/ha). Oil crops, legumes, forages, and some vegetables require more sulphur than phosphorus for optimal yield and quality. Plants contain as much sulphur as phosphorus, with an average content of approximately 0.25%. Usual recommendations for correcting deficiency are 15 to 30 kg S/ha for cereal crops and silage grass; and 25 to 50 kg S/ha for oil crops, legume, sugarcane, and some vegetable crops. (TSI 2018).

Table 16. S demand of agricultural crops. Sources : Malle Järvan, (ECRI) and Government of Saskatchewan. (2017)

Crop	S demand, kg per tonne of crop yield
Grasses	1.9
Alfalfa	2.7
Cereals	2
Oilseed rape	11
Silage maize	1.5 per DM tonne

An excess supply of S is not considered an environmental problem. However, it cannot be excluded that a large excess supply in the future will be considered as a problem especially in catchment areas for P-sensitive lakes. Depending on SAT and crop choices results in different S doses in relation to the need. Using 2 l acid per m^3 of slurry delivered at 30 t ha^{-1} results in an application of 34 kg S ha^{-1}. This is about the requirement for need winter oilseed rape, but it is twice the requirements of cereal crops. (SEGES 2015).

The calculation of the reduction of mineral S cost by slurry acidification consists next steps:

1) Calculation of S amount spread with acidified slurry
2) Determining S demand of crop – see the table 14.
3) Calculation of required S amount covered by acidified slurry
4) Mineral S cost
5) Reduction of mineral S cost for farm crop nutrition

Calculation of S amount spread with acidified slurry

$$Q_S = a_a a_{ha} m_{S,1}$$

where Q_S - S amount applied to the field with acidified slurry kg ha^{-1}; a_a – amount of acid used for acidification of one cubic meter of slurry l m^{-3}; a_{ha} – amount of slurry spread to the field, m^3 ha^{-1} $m_{S,1}$ – S weight in 1 liter acid solution, kg l^{-1};

The S content in sulphuric acid can be calculated by the molar masses of S and H_2SO_4, which are correspondingly 32 and 98 (personal contact with Kaspar Vulla, ECRI). The portion of S in H_2SO_4 corresponds to the relation of the molar masses – 32/98. For the calculation of content of pure S in acid solution, the relation should be multiplied with weight of acid and solution concentration:

$$m_{S,l} = \frac{c_{H_2SO_4} m_a M_S \rho_a}{100 M_{H_2SO_4}},$$

where c_{H2SO4} is acid concentration, m_a is weight of acid solution, M_S –molar mass of S and M_{H2SO4} molar mass of H_2SO_4; ρ_a is density of sulphuric acid kg l^{-1}

Table 17. Density of sulphuric acid by different concentrations. (Steffen's Chemistry Pages. 2018)

H_2SO_4 concentration, %	Density ρ_a at 20°C, kg l^{-1}
50	1.3951
...	...
90	1.8144
91	1.8195
92	1.824
93	1.8279
94	1.8312
95	1.8337
96	1.8355
97	1.8364
98	1.8361
99	1.8342
100	1.8305

Thus the S content in 1 liter of 94% sulphuric acid solution is:

$$m_{S,1} = \frac{94\% \cdot 1\ kg\ \cdot 32 \cdot 1.8312}{100 \cdot 98} = 0.562\ kg\ l^{-1}.$$

Calculation of crops S demand per hectare

The crop S demand kg per hectare is calculated by multiplying the value in table 16 with the planned yield tonnes per hectare.

$$m_{S,crop} = h m_{S,crop,t}$$

where $m_{S,crop}$ – crop S demand per hectare, kg ha^{-1}; h – planned crop yield, t ha^{-1}; $m_{S,crop,t}$ – crop S demand per tonne of yield, kg t^{-1} (table 16).

If several crops are fertilised with acidified slurry in the farm, then the average S demand weighted by crop areas have to be calculated:

$$m_{S,crop} = \frac{\sum_{i=1}^{n} A_{c,i} m_{S,crop,i}}{A}$$

where A is the total area fertilised with acidified slurry in the farm, ha; $A_{c,i}$ is area of crop *i*, fertilised with acidified slurry, ha; $m_{S,crop,i}$ is S demand of crop *i* per hectare, kg ha^{-1}; n is number of crops fertilised with acidified slurry in the farm.

Calculating mineral S cost

Generally the mineral S is one component in complex fertiliser. The most easy way is to use some NS fertiliser data to calculate S price. First the N price is calculated by mineral N fertiliser price (table 14) and then the S cost is calculated with formula:

$$p_S = \frac{0.1\left(p_{f,NS} + p_d + p_h\right) - c_N p_N}{c_s}$$

where p_S is mineral S element cost € kg^{-1}; $p_{f,NS}$ is NS mineral fertiliser price € t^{-1} (table 18); %; c_S is S content in fertiliser, % (table 18).

Table 18. Mineral S- fertiliser prices, mineral S prices (100% S) prices in Baltic Sea Region. Prices are without VAT.

Country	Fertiliser	Price, with delivery € t^{-1}	Price of mineral S € kg^{-1}
Estonia	AmmoniumSulphate 21N-24S	209	0.24
Latvia	AmmoniumSulphate 21N-24S	190	0.21
Russia	NS 30:6	170	0.15
Sweden	NS 27-4	220	0.85
Lithuania	AmmoniumSulphate 21N-24S	200	0.15
Germany	ASS (27% / 13%) 13.12.2017	236	0.18
Finland	AmmoniumSulphate 21N-24S	245	0.41
Poland	Ammonium sulphate 21N-24S	230	0.26
Belarus	Ammonium sulphate 21N 24S	127	0.11
Denmark	NS 27-S24	366	0.65

Calculation of mineral S fertiliser handling cost

If crops are fertilised with NS fertiliser, then the handling costs are divided by portion element in fertiliser.

The N portion of handling costs was calculated in chapter 3.10. The S portion of handling costs can be calculated with formula

$$p_{S,h} = p_h - p_{N,h}$$

Calculating the reduction of mineral S cost for farm crop nutrition

If the crop S demand per hectare is smaller than S amount applied with slurry, then the crop benefits only the part of slurry S and rest of S is presumed to leach without use.

Thus, if crop S demand per hectare is equal or bigger than S amount applied with slurry

$$m_{S,crop} \geq Q_S,$$

then in the S-fertiliser cost reduction calculation of the total amount of S applied with slurry is taken into account

$$m_S = Q_S$$

else in the S-fertiliser cost reduction calculation only the S amount needed by crop is taken into account

$$m_S = m_{S,crop}$$

where $m_{S,crop}$ – crop S demand kg ha^{-1}.

The reduction of mineral S cost

$$r_S = \frac{m_S}{a_{ha}}$$

where r_S – reduction of mineral N cost by slurry acidification € m^{-3}.

3.12. Effect on slurry storage costs

3.12.1. Covering of storage

Covers for liquid manure storages significantly reduce odour and gas emissions by creating a physical barrier between the liquid and the air. Covers are classified as either impermeable or permeable. Impermeable covers do not allow any gases coming from the manure to be emitted to the atmosphere. On the other hand, permeable covers permit transmission of some gases. Various types of covers have been tried and each has its own advantages and disadvantages. The overview about different covers is given in the table 19.

Table 19. The overview about different slurry storage covers (English and Fleming, 2006)

Permeable:	Impermeable:
a) Straw	a)Inflatable Plastic (positively pressurized)
b) Geotextile	b) Floating Plastic (negatively pressurized)
c) Clay Balls	c) Floating Plastic
d) Perlite	d) Suspended Plastic
e) Rigid Foam	d) Concrete
f) Oil	e) Wood/Steel
g) Natural Crust	
h) Corn Stalks, Sawdust, Wood Shavings,	

Rice	Hulls,	Ground	Corncobs,	Grass Clippings

In the present analyses the storing of acidified slurry is compared to different slurry storage covers:

1) Clay balls like Fibo or Leca;
2) Hexa-Cover plastic plates;
3) Chopped straw;
4) Peat;
5) Rapeseed oil
6) Natural crust.
7) Tent cover

The calculation consist the computation of:
1) surface area of storage ;
2) amount of cover material ;
3) cost of cover material with placing ;
4) nitrogen loss from storage;
5) cost of additional mineral nitrogen to replace the loss
6) cost of handling of additional mineral nitrogen.
7) sum of costs per cubicmeter of slurry.

The minimum value of the sum shows the most economic solution.

Calulation of surface area of slurry storage in farm

The surface area of acidified slurry storage is calculated by capacity of storage and height of storage from bottom to the edge.

$$S_{st} = \frac{C_{st}}{h_{st}}$$

where S_{st} – surface area of slurry storage, m^2; C_{st} – capacity of slurry storage, m^3; h_{st} – height of slurry storage from bottom to the edge, m.

The capacity of slurry storage depends on annual slurry production. In the national regulations is determined the required minimum manure storage capacity, in months (table 20).

Table 20. the required minimum manure storage capacity, in months, determined in national regulations. The data are asked from project partners.

Country	Minimum manure storage capacity, in months
Estonia	8
Latvia	8
Russia	6 month for cattle and poultry manure and 12 month for pig manure (see also the info below the table)
Sweden	It is very much up to farm size but in general 10 month for pig farms and 8 month for cattle farms (part of the time the animals are outdoors

	in summer, several spreading opportunities during summer on grassland). However, larger farms could have harder demands (individual permits) and small farms a bit less storage period.
Lithuania	6
Germany	6
Finland	12 months. For farms with grazing animals it is possible to decrease manure left on pasture from storage volume. In this case the minimum capacity is typically 8 months. Capacity can also be decreased if manure is given out from the farm, e.g. for processing.
Poland	6 months for liquid natural fertilizers. 5 months.for solid natural fertilizers.
Belarus	6
Denmark	9 as general rule.

Russia

«Recommended Practice for Engineering Designing of Animal and Poultry Manure Removal Systems and the Systems of Animal and Poultry Manure Preparation for Application»

Management Directive for Agro-Industrial Complex (РД-АПК) 1.10.15.02-17

13.1 The period of storage of all types of manure and litter should be determined by calculation depending on:
- duration of periods of autumn-spring off-road;
- availability of free agricultural land for spreading of manure and litter;
- epizootic status of a farm;
- climatic and organizational conditions.

The period should be from 4 to 8 (for cattle manure) and from 8 to 12 months (for pig manure), depending on the structure, moisture content of manure and storage technology.

Recommendations for North-West Russia:
Currently the main manure processing technique is long-term storage (maturing): above 60% of agricultural farms consider it as a basic one. Up to 95% of slurry and liquid manure is processed by this technique. It is characterized by long processing periods:
● Storage (maturing) of cattle manure and poultry manure – 6 months, pig slurry – 12 months;

Liquid fraction:
● Maturing of the liquid fraction of cattle manure after separation – at least 4 months;
● Maturing of the liquid fraction of pig slurry after separation in sectional storages in spring and summer – 6 months; during the period of autumn accumulation – 9 months.
(Management Directive for Agro-Industrial Complex 1.10.15.02-17).

Calculation of amount of cover materials

By some cover materials the amount of material depends on thickness of cover material layer. Suggested layer thicknesses are for (Liquid Manure Storage Covers. 2006):

1) clay balls (fraction 10–20 mm) – 10 cm
2) rapseed oil – 0,5 cm
3) chopped straw – 10–15 cm
4) peat – 15–20 cm

The amount of such kind of cover materials is calculated with the formula:

$$a_{st.c} = \frac{S_{st} h_{st.c}}{100}$$

where $a_{st.c}$– amount of slurry storage cover material, m^2; $h_{st,c}$ – height of slurry storage cover material layer, cm.

The amount of Hexa-Cover (Figure 5) plates in square meters is equal to the surface area of the storage. The plates have bigger effect if the slurry has no or little natural crust like by pig slurry on separated cattle slurry.

Figure 5. Left: A lagoon covered with Hexa-Cover plates. Middle: Hexa-Cover plates. Right: A round tank covered with Hexa-Cover plates. (State of Green, 2017)

By the calculation of area of tent cover should be taken into account that the cover has form of conus and borders have to reach over storage brim (figure 6). The tent requires also supporting structure and facilities to fasten the tent borders.

Figure 6. A slurry storage covered with tent. Denmark, April 2017. Picture by Kalvi Tamm.

Calulation of cost of cover materials

The cost of cover material is calculated with formula

$$p_{st.c} = \frac{p_{st.c.u} a_{st.c}}{D_{st.c}}$$

where $p_{st.c.u}$– price of cover material with placing, € m^{-2} (Capital cost in Table 21); $D_{st,c}$ – lifetime of cover material, years.

Table 21. Slurry storage cover material data required in economic calculations (English, S. & Fleming, R. 2006; EULS, 2013; VanderZaag, et al 2008)

Cover material	**Layer thichnes, cm**	**Capital cost, € m^{-2}**	**Lifetime of cover, years**	**NH_3 loss reduction, %**
Fibo clay balls (fraction 10-20 mm)	10	5.4	5	80
Hexa-cover plates		33	25	90
Chopped straw	10–15	0.4	0.5	65
Tent cover		40	10	95
Floating foil		8,5	7	85
Rapeseed oil	0.3–0.6	3.8	0.5	80
Peat	10–20	1.7	0.5	85

Calulation of nitrogen loss from storage

If ex-animal N_{tot} is in the calculations used, then NH_3-N loss in storage is calculated with formula

$$L_s = \frac{k_s(100 - r_c)}{10000}\left(a_{N_{tot}} - L_b\right)$$

where L_s – NH_3-N loss in storage kg m^{-3}; a_{Ntot} – amount of total nitrogen N_{tot} in slurry (ex-animal) kg m^{-3}; k_s– loss of NH_3-N from artificially not covered storage

% (Table 22); r_c–NH_3-N loss reduction rate from artificially covered storage % (Table 21); L_b – NH_3-N loss in barn kg m^{-3}; (See section 3.8).

If ex-housing N_{tot} is in the calculations used (e.g. slurry sample is taken from pumping pit), then NH_3-N loss in storage is calculated with formula

$$L_s = \frac{k_s(100 - r_c)}{10000}(a_{N_{tot}})$$

The NH_3 –N loss from slurry storage is given in the table 22.

Table 22 . NH_3-N loss from artificially not covered slurry storages (EULS 2013)

Cover material	**NH_3-N loss from storage, %**	
	Tank	**Lagoon**
Uncovered	14	24
Natural crust	10	20

3.13. Yield response

In the calculation model is presumed that yield is same in both scenarios:

1) Slurry is acidified
2) Slurry is not acidified and NH_4-N loss is compensated with mineral fertiliser.

In reality, the slurry acidification can also have additional decreasing or increasing impact on the field even though the N amount would be same on both scenarios. (Figure 7.).

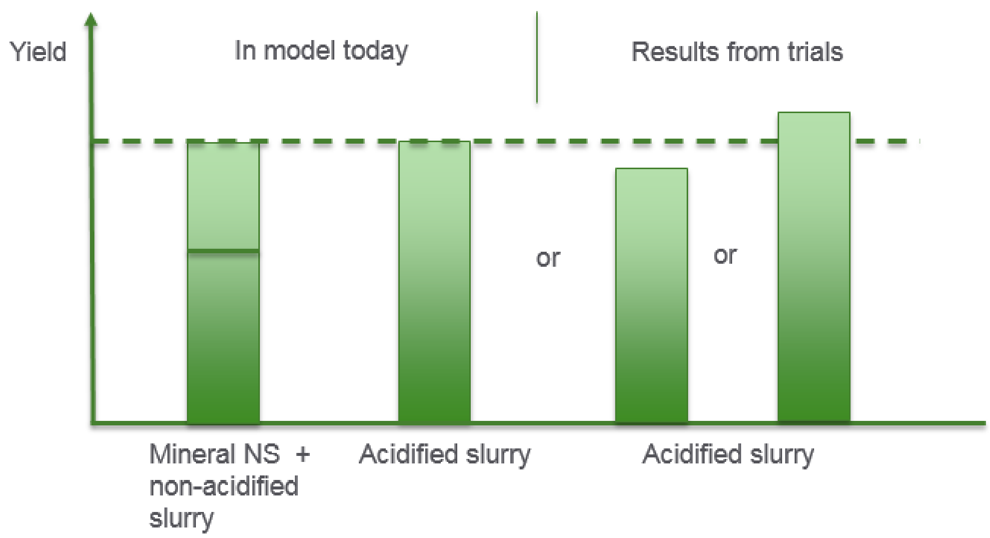

Figure 7. Yield response to the N amount given with different fertilisers. Mineral NS is mineral fertiliser containing nitrogen and sulphur.

The field trials were made in Baltic Slurry Acidification project to compare the yield responses of acidified and non-acidified slurries.

Table 18. Dry matter (DM) yield response calculated by data collected form grassland trial in Estonia, 2018.

Trial variant	Slurry, m^3 ha^{-1}	N, kg ha^{-1}	DM yield, 2.+3. cut, kg ha^{-1}	Additional DM yield with fertilisers, kg ha^{-1}	Additional DM yield with fertilisers, per kg of N, kg kg^{-1}
Control/ Untreated		0	1340		
Mineral fertilizer		65	2540	1200	18.5
Untreated slurry	43.3	67.1	2070	730	10.9
Acidified slurry	43.3	69.3	2350	1010	14.6

By the data in the Table 18, the additional DM yield for untreated slurry, if N amount would be same as by acidfied slurry, would be theoretically 730 + (69.3 - 67.1) × 18.5 = 770 kg ha^{-1}. (The N difference is here compensated with mineal N.)

It means that, theoretically, even by same amounts of N kg ha^{-1}, the acidified slurry would give 1010 – 770 = 240 kg ha^{-1} or 240 : 43.3 = 5,54 kg m^{-3} additional DM yield. If to calculate with DM content of silage is 35%, then the additional silage amount would be 15.8 kg m^{-3}. It should be taken into account in economic calculations.

Background information about this trial:

1) The 1. cut yield taken before difffernciated fertilisation show that the yield differences between variants were very minor.

2) Before 1. cut all plots got 35 kg P ha^{-1} and 42 kg S ha^{-1} with superphosphate, to cover P and S demand of plants.

In the economic analyses, the additional slurry acidification effect on yield is calculated with formula:

$$r_y = -1\,\frac{\Delta_y(p_y - p_{y,h})}{1000}$$

where r_y is slurry acidfication effect on yield, € m^{-3}; p_y is yield price, € t^{-1}; $p_{y,h}$ is yield handling cost, € t^{-1} (Table 23); and Δ_y is yield difference, kg m^{-3}.

The positive yield effect should be substracted from other costs, and therefore it is calculated here as cost reduction and mutiplied with -1.

Table 23. Yield prices in different prices in Baltic sea region. Prices are without VAT.

Country	Yield	Yield price, € t^{-1}	Yield handling cost € t^{-1}

Estonia	Rolled dry grass silage	50	15
Estonia	Barley	130	47
Estonia	Wheat	149	47
Latvia	Rolled dry grass silage	25	10.8
Latvia	Barley	124	11.8
Latvia	Wheat	158	11.8
Russia	Rolled dry grass silage	60	10
Russia	Barley	73	15
Russia	Wheat	97	15
Sweden	Rolled dry grass silage	140 (DM)	
Sweden	Barley	112	30
Sweden	Wheat	143	30
Lithuania	Rolled dry grass silage	60	20
Lithuania	Barley	130	25
Lithuania	Wheat	150	25
Germany	Rolled dry grass silage	30	10+1.1 per km
Germany	Barley	140	10–15 depending on field distance
Germany	Wheat	148	10–15 depending on field distance
Finland	Rolled dry grass silage	120 (DM)	28
Finland	Barley	140	50
Finland	Wheat	165	50
Poland	Rolled dry grass silage	19	12
Poland	Barley	144	
Poland	Wheat	151	
Belarus	Rolled dry grass silage	22	8
Belarus	Barley	140	13.2
Belarus	Wheat	130	13.2
Denmark	Rolled dry grass silage	140 (DM)	
Denmark	Barley	112	30
Denmark	Wheat	143	30

4. Method of sensitivity analysis

The calculations are made for every country separately, with input data collected by country presenters during project.

Compared are acidified slurry versus non-acidified slurry. The spreading technology is band spreading for both slurries. No incorporation if slurry is acidified and incorporation within less than 12 hours if slurry is not acidified.

Calculated are cost differences between non-acidified and acidified slurry, € m^{-3}. The difference is cost decrease by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

The cost decrease by use of acidified slurry is also named as cost-benefit of slurry acidification.

The cost benefit of SAT= sum of costs by non-acidification of slurry- sum of costs by use of SAT.

The higher is the cost benefit of a SAT, the bigger postitive economic effect has the use of the SAT.

For cattle slurry the housing type is loose housing, mobile manure removal 2–3 times per day, little bedding.

Storage type is tank with crust.

Sensitivity analyses is made for the following parameters:

- annual slurry amount;
- type of storage cover by in-house acidification, if slurry is not acidified;
- the acid consumption to acidify slurry;
- content of total N in slurry before acidification;
- price of mineral N;
- price of mineral S.

In all calculation, only one parameter was changed at a time. The basic values for analysed parameters are in following tables and lists shown in bold.

In the analyses of yearly amount of slurry are included the capacities of one SAT installation, highlighted in report “Baltic Slurry Acidification 6.1 Market Potential Analysis” (pg 20):

- in-stable: 9,286 tons per installation
- in-storage: 21,333 tons per installation
- in-field: 33,636 tons per installation.

These amounts are approximated to 9,000, 21,000 and 33,000 m^3 per year.

Table 24. Yearly amount of slurry and corresponding number of animal

Dairy cows		Fatteners	
Yearly amount of slurry, m^3	Number of animal	Yearly amount of slurry, m^3	Number of animal per year
1,200	50	500	1,000
2,400	100	2,500	5,000
9,000	375	5,000	10,000
12,000	500	9,000	18,000
21,000	**875**	**21,000**	**42,000**
24,000	1,000	33,000	66,000
33,000	1,375		
48,000	2,000		

Type of storage cover by in-house acidification, if slurry is not acidified;

- **no cover;**
- chopped straw;
- fibo clay balls (fraction 10–20 mm);
- floating foil;

- hexa-cover plates;
- peat;
- rapeseed oil;
- tent cover.

The acid consumption to acidify slurry is in calculations: 1, 2, 3, 4, 5 or 7 litres per cubic-meter of slurry. The basic value were for in-field 3, and in-storage 3.6 in-house 4.5, litres per cubic-meter of slurry for cattle slurry. For pig slurry are these values 3.5, 3 and 2.6.

Table 25. The **content of total nitrogen** N_{tot} in slurry before acidification

Diary cow slurry		Fattener slurry	
Ex animal	Ex-storage	Ex animal	Ex-storage
In house SAT	In storage and in-field SAT	In house SAT	In storage and in-field SAT
4	3	5	4
5	4	6	5
5.9	**4.74**		**5.5**
6	5	**7.0**	6
7	6	8	7

Price of mineral N differs by country. So, the price sent by contact person is changed to the levels: -50,-20, **0**,+20 and +50%.

Price of mineral S also differs by country So, the price sent by contact person is changed to the levels: -50,-20, **0**,+20 and +50%.

5. Results

5.1. Belarus

5.1.1. Annual slurry amount, Belarus

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry.

The acid price in the calculations is 30 € t^{-1} for in-house acidification and 101 € t^{-1} for in-storage and in-field acidification. N-fertilisers is Urea N46, 219 € t^{-1}. NS-fertiliser N21-S24, 127 € t^{-1}. Thus N price 0.48 € kg^{-1} and S price 0.11 € kg^{-1}. The prices of project partner countries are between 0.48–1 and 0.11–0.8 5€ kg^{-1} respectively.

The in-house acidification has in Belarus significantly higher cost-benefit comapred to other SATs. The reason is that by in-house SAT is used bulk acid which is transported by big tank truck and has much lower price compared to the case if acid is transported in the IBC tanks, which is used by other SATs.

Table. 26 The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit.

SAT	Dairy cows: Annual slurry amount, m^3	Dairy cows: Number of animal	Fatteners: Annual slurry amount, m^3	Fatteners: Number of animal per year
In-house	11,280	470	6,620	13,240
In-storage	NA	NA	5,323	10,646
In-field	NA	NA	20,422	40,844

Table 27. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1,200	10.50	5.93	**-4.57**	7.87	5.83	**-2.04**	11.91	5.79	**-6.12**
2,400	6.33	4.53	**-1.80**	5.30	4.42	**-0.88**	7.25	4.39	**-2.86**
9,000	2.93	2.75	**-0.18**	2.76	2.64	**-0.12**	3.19	2.61	**-0.58**
12,000	2.43	2.47	**0.04**	2.44	2.36	**-0.08**	2.73	2.33	**-0.40**
21,000	1.83	2.02	**0.19**	1.96	1.91	**-0.05**	2.08	1.88	**-0.20**
24,000	1.68	1.92	**0.24**	1.86	1.82	**-0.04**	1.96	1.79	**-0.17**
33,000	1.46	1.72	**0.26**	1.67	1.62	**-0.05**	1.71	1.58	**-0.13**
48,000	1.22	1.52	**0.30**	1.48	1.41	**-0.07**	1.47	1.38	**-0.09**

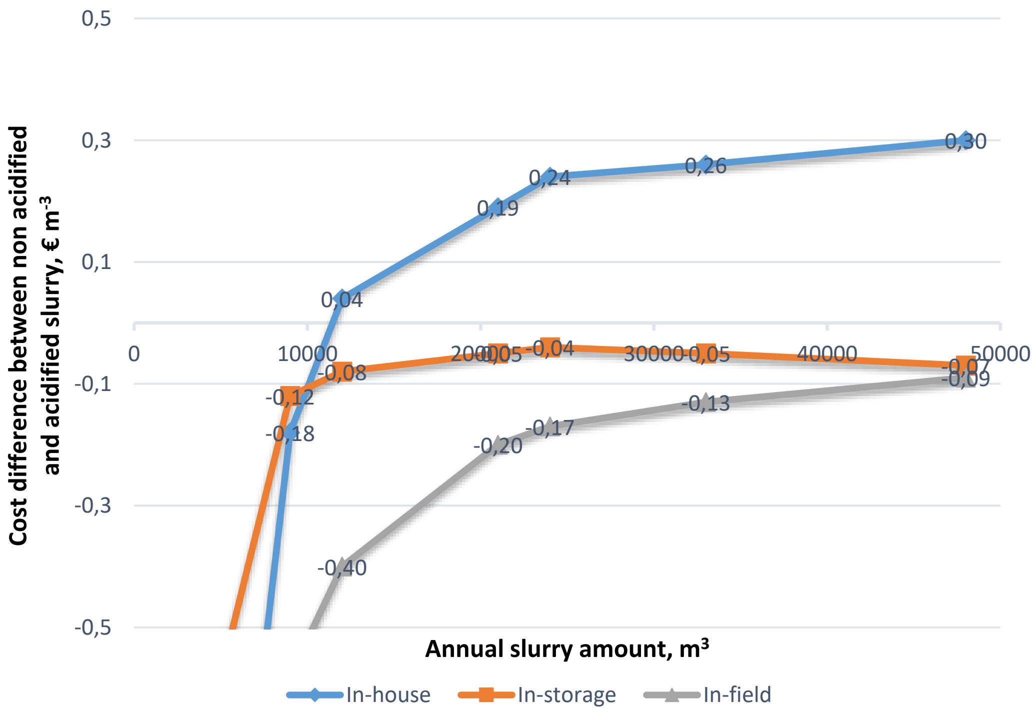

Figure. 8. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Table 28. Fattener slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
500	36.84	8.77	**-28.07**	13.39	8.31	**-5.08**	23.34	8.27	**-15.07**
2,500	8.70	4.84	**-3.86**	4.93	4.39	**-0.54**	6.88	4.35	**-2.53**
5,000	4.69	3.80	**-0.89**	3.38	3.35	**-0.03**	4.32	3.31	**-1.01**
9,000	2.90	3.13	**0.23**	2.51	2.68	**0.17**	3.02	2.64	**-0.38**
21,000	1.37	2.40	**1.03**	1.71	1.95	**0.24**	1.90	1.91	**0.01**
33,000	0.88	2.10	**1.22**	1.42	1.65	**0.23**	1.53	1.61	**0.08**

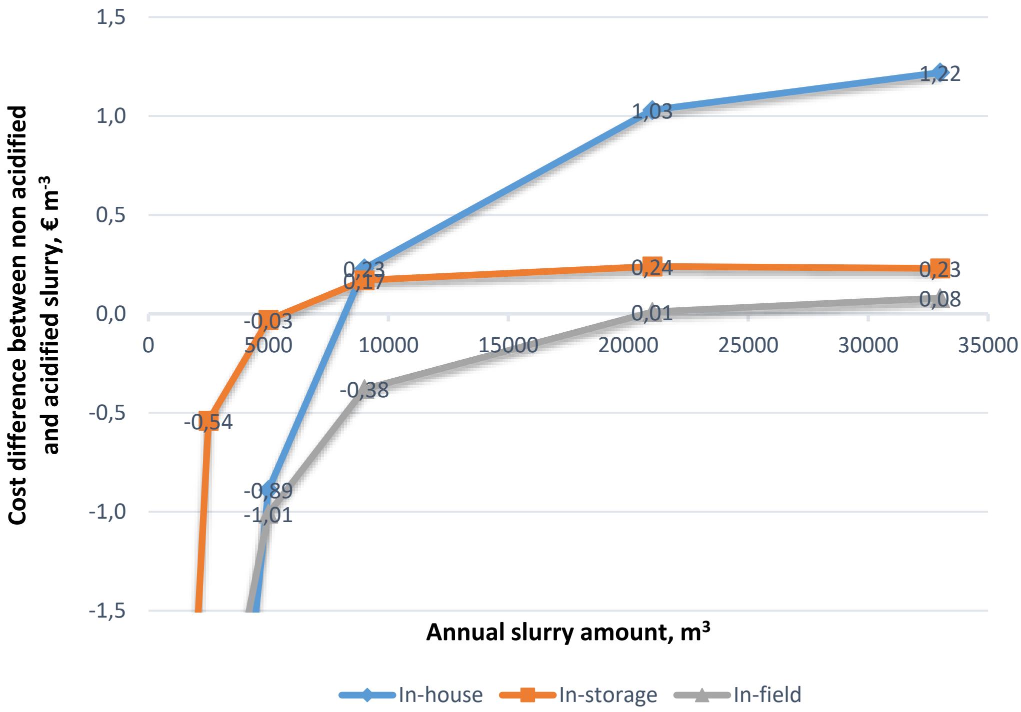

Figure 9. The cost decrease (€ m^{-3}) by use of fattener slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

5.1.2. Cover type, Belarus

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 10 and 11 show also that the order of cover types is same for both, cattle and big slurries.

In Belarus, the required minimum manure storage capacity is 6 months. In this analysis is presumed that animal are housed in all year around and storage depth is 5 m. The capital cost of slurry storage cover calculated for these conditions are shown in the table 21.

Table 29. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

	In-house		
Cover type	Acid	No acid	**Dif.**
No cover	1.83	2.02	**0.19**
Chopped straw	1.95	2.02	**0.07**
Fibo clay balls (fraction 10-20 mm)	1.98	2.03	**0.05**
Floating foil	1.99	2.04	**0.05**
Hexa-cover plates	2.00	2.04	**0.04**
Peat	1.99	2.26	**0.27**
Rapeseed oil	1.98	2.68	**0.70**
Tent cover	2.01	2.31	**0.30**

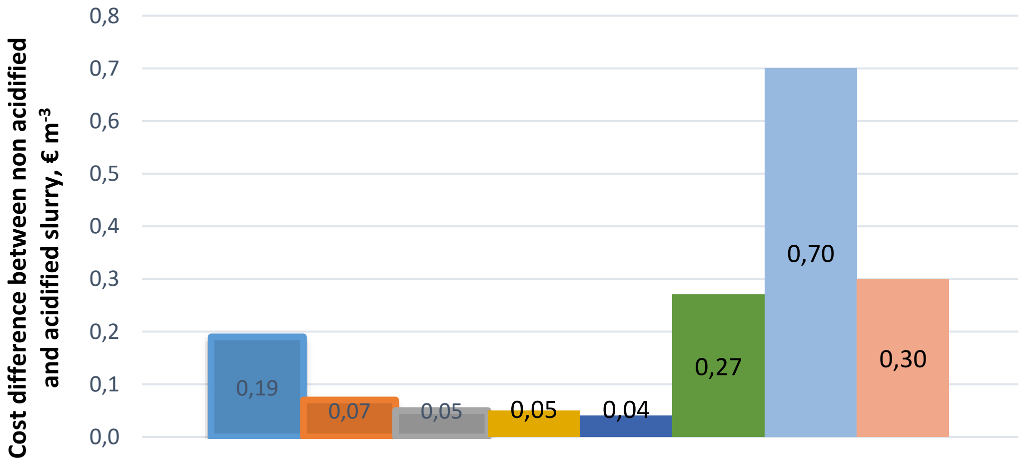

Figure 10. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Table 30. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	In-house Acid	In-house No acid	**Dif.**
No cover	1.37	2.40	**1.03**
Chopped straw	1.53	2.38	**0.85**
Fibo clay balls (fraction 10-20 mm)	1.56	2.39	**0.83**
Floating foil	1.57	2.40	**0.83**
Hexa-cover plates	1.59	2.40	**0.81**
Peat	1.57	2.61	**1.04**
Rapeseed oil	1.56	3.04	**1.48**
Tent cover	1.60	2.66	**1.06**

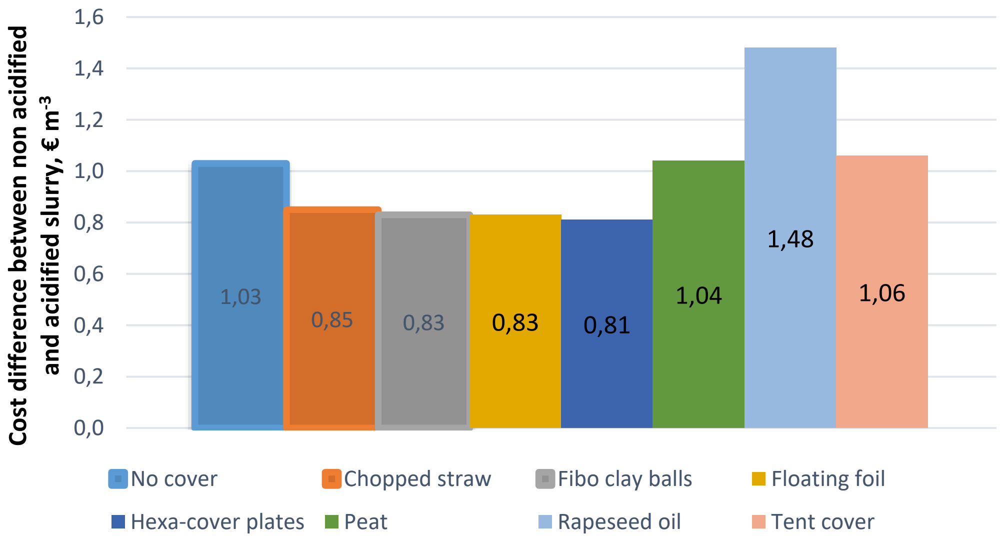

Figure 11. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners.

5.1.3. Acid consumption, Belarus

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The higher is the acid price, the bigger is the impact of acid amount on total costs of slurry acidification. The cattle slurry in-storage and in-field acidification would have cost benefit if acid amount would be less than 3.5 and 2.5 litre per cubicmeter of slurry correspondigly.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) decreases if acid content in slurry rises.

If acid consumption ↑ 1 l m^{-3}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↓0.16 € m^{-3}	↓0.15 € m^{-3}
in-storage SAT:	↓0.30 € m^{-3}	↓0.30 € m^{-3}
in-field SAT:	↓0.31 € m^{-3}	↓0.31 € m^{-3}

Acid content change in slurry has lowest impact by in-house SAT and biggest by in-field SAT. The reason is that the acid price for in-house SAT is significantly lower (30 € t^{-1}) than by other SATs (101 € t^{-1}).

Table 31. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	1.29	2.02	**0.73**	1.21	1.91	**0.70**	1.49	1.88	**0.39**
3	1.58	2.02	**0.44**	1.77	1.91	**0.14**	2.08	1.88	**-0.20**
4	1.74	2.02	**0.28**	2.08	1.91	**-0.17**	2.40	1.88	**-0.52**
5	1.91	2.02	**0.11**	2.38	1.91	**-0.47**	2.71	1.88	**-0.83**
7	2.24	2.02	**-0.22**	3.00	1.91	**-1.09**	3.35	1.88	**-1.47**

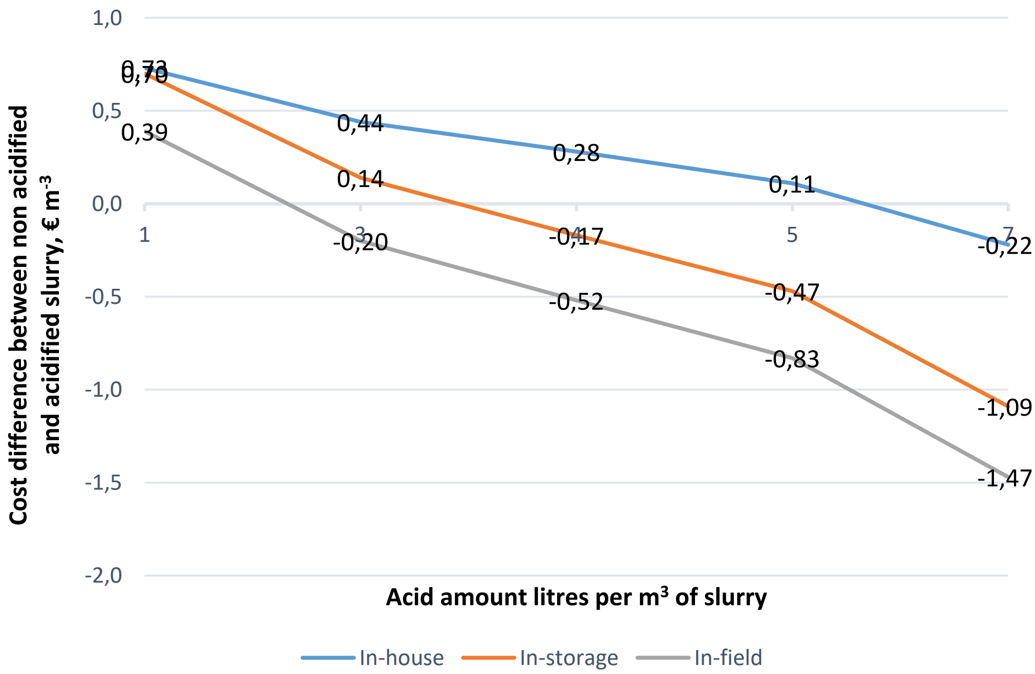

Figure 12. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

Table 32. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	1.04	2.40	**1.36**	1.15	1.95	**0.80**	1.44	1.91	**0.47**
3	1.28	2.40	**1.12**	1.71	1.95	**0.24**	2.03	1.91	**-0.12**
4	1.45	2.40	**0.95**	2.02	1.95	**-0.07**	2.35	1.91	**-0.44**
5	1.62	2.40	**0.78**	2.32	1.95	**-0.37**	2.67	1.91	**-0.76**
7	1.95	2.40	**0.45**	2.94	1.95	**-0.99**	3.30	1.91	**-1.39**

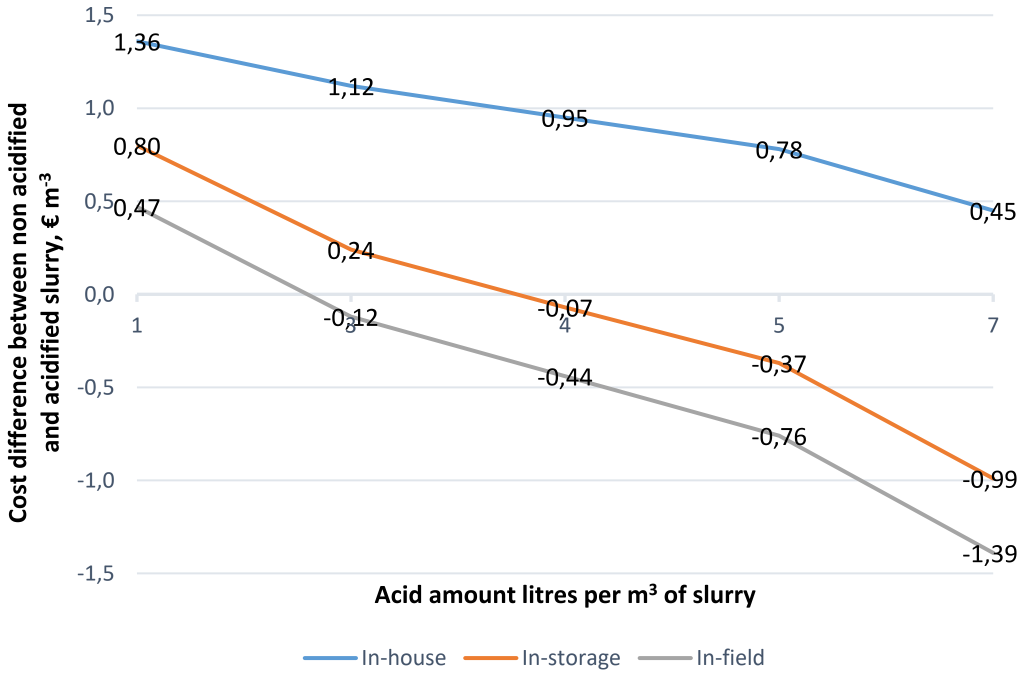

Figure 13. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

5.1.4. N_{tot} in slurry, Belarus

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

If N_{tot} content in slurry ↑ 1 kg m^{-3} , then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.12 € m^{-3}.	↑0.25 € m^{-3}.
in-storage SAT:	↑0.10 € m^{-3}.	↑0.10 € m^{-3}.
in-field SAT:	↑0.08 € m^{-3}	↑0.08 € m^{-3}.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.

Table 33. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content	In-house			In-storage			In-field		
kg m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
3				2.05	1.86	**-0.19**	2.15	1.83	**-0.32**
4	1.97	1.93	**-0.04**	1.99	1.89	**-0.10**	2.10	1.86	**-0.24**
5	1.90	1.98	**0.08**	1.93	1.93	**0.00**	2.05	1.89	**-0.16**
6	1.82	2.02	**0.20**	1.87	1.97	**0.10**	2.00	1.92	**-0.08**
7	1.74	2.07	**0.33**						

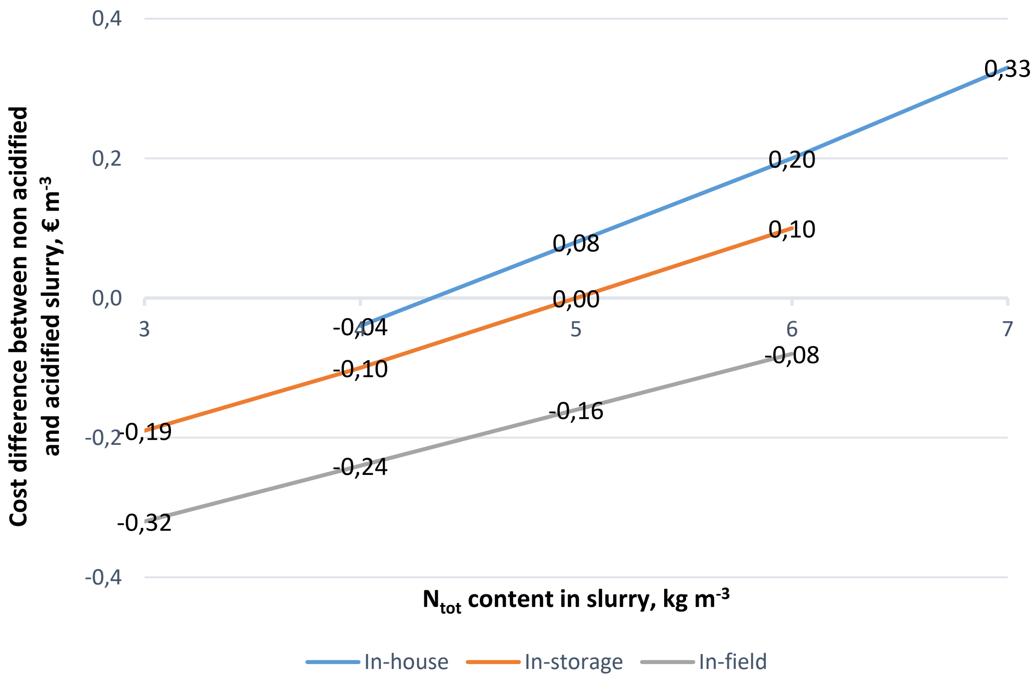

Figure 14. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Table 34. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content	In-house			In-storage			In-field		
kg m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
4				1.80	1.89	**0.09**	1.97	1.86	**-0.11**
5	1.68	2.21	**0.53**	1.74	1.93	**0.19**	1.93	1.89	**-0.04**
6	1.52	2.31	**0.79**	1.68	1.97	**0.29**	1.88	1.92	**0.04**
7	1.37	2.40	**1.03**	1.62	2.00	**0.38**	1.83	1.95	**0.12**

8	1.21	2.49	**1.28**

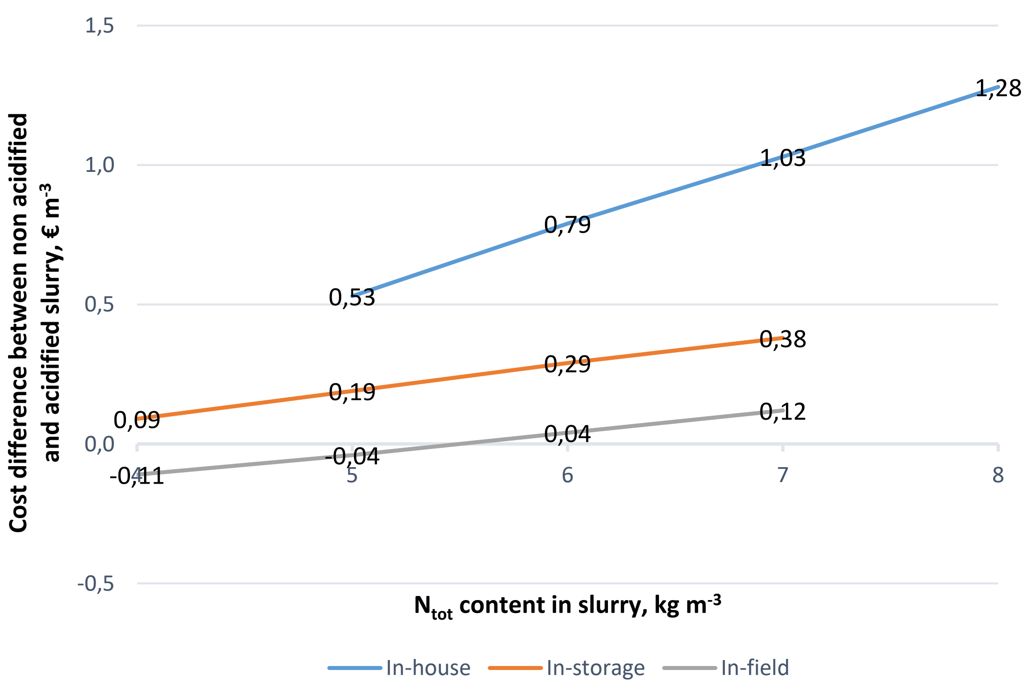

Figure 15. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

5.1.5. N price, Belarus

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

N price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	<u>cattle slurry</u>	<u>pig slurry:</u>
in-house SAT:	↑0.090 € m^{-3}.	↑0.21 € m^{-3}.
in-storage SAT:	↑0.054 € m^{-3}.	↑0.07 € m^{-3}.
in-field SAT:	↑0.044 € m^{-3}	↑0.05 € m^{-3}.

The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.
Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

Table 35. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N	In-house	In-storage	In-field

price € kg^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.24	2.04	2.02	**-0.02**	2.09	1.91	**-0.18**	2.18	1.88	**-0.30**
0.384	1.91	2.02	**0.11**	2.01	1.91	**-0.10**	2.12	1.88	**-0.24**
0.48	1.83	2.02	**0.19**	1.96	1.91	**-0.05**	2.08	1.88	**-0.20**
0.576	1.74	2.02	**0.28**	1.90	1.91	**0.01**	2.04	1.88	**-0.16**
0.72	1.61	2.02	**0.41**	1.83	1.91	**0.08**	1.97	1.88	**-0.09**

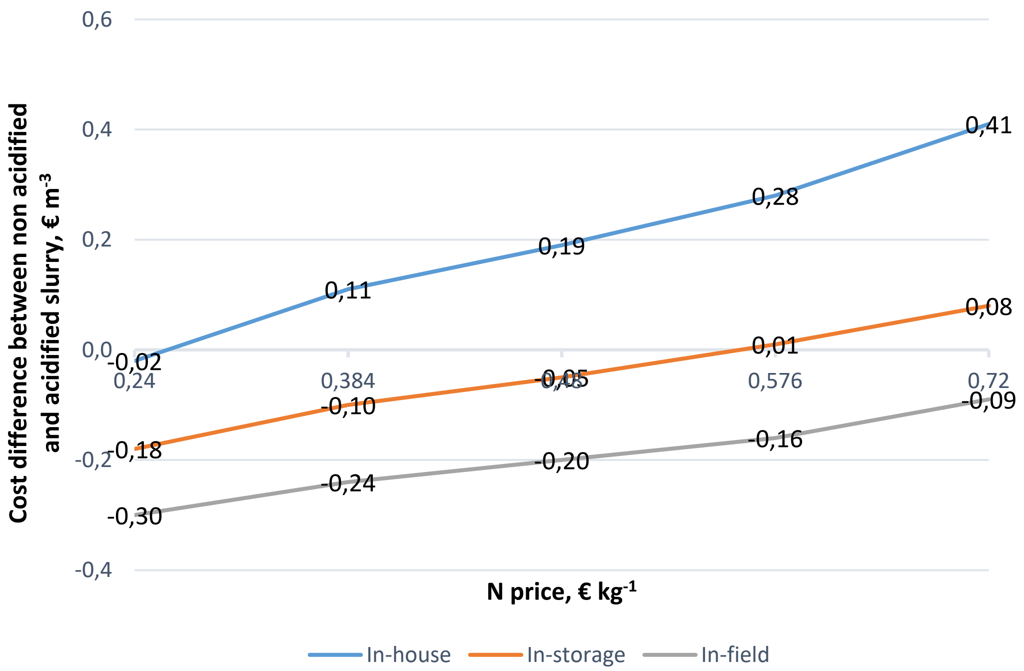

Figure 16. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

Table 36. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.24	1.87	2.40	**0.53**	1.87	1.95	**0.08**	2.03	1.91	**-0.12**
0.384	1.57	2.40	**0.83**	1.77	1.95	**0.18**	1.95	1.91	**-0.04**
0.48	1.36	2.40	**1.04**	1.71	1.95	**0.24**	1.90	1.91	**0.01**
0.576	1.16	2.40	**1.24**	1.65	1.95	**0.30**	1.85	1.91	**0.06**
0.72	0.85	2.40	**1.55**	1.55	1.95	**0.40**	1.77	1.91	**0.14**

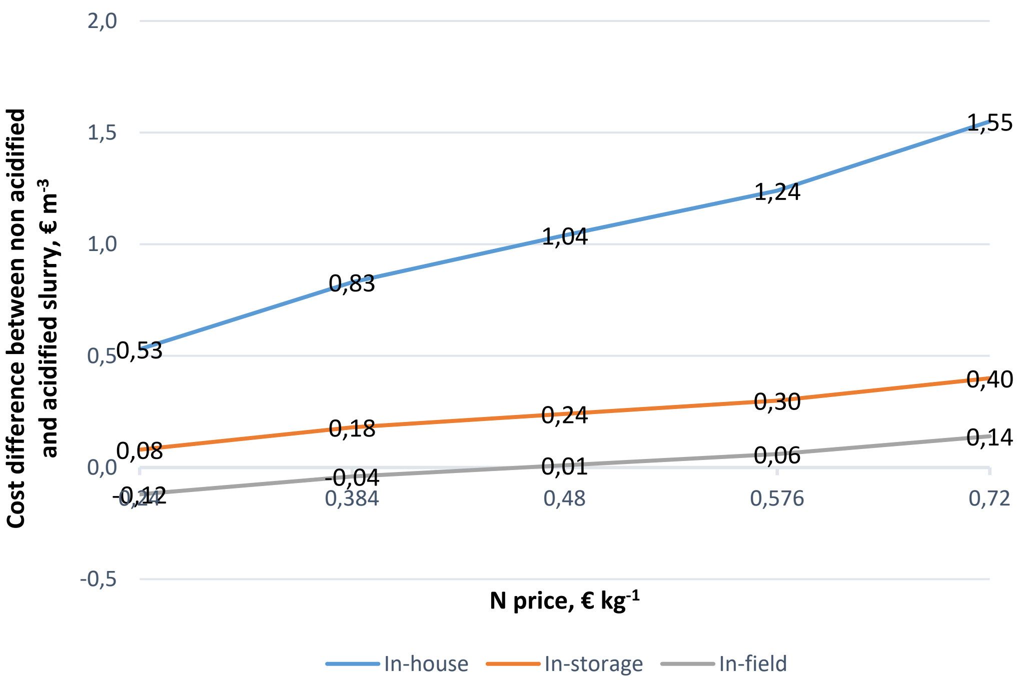

Figure 17. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

5.1.6. S price, Belarus

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

S price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	<u>cattle slurry</u>	<u>pig slurry:</u>
in-house SAT:	↑0.08 € m^{-3}.	↑0.11 € m^{-3}.
in-storage SAT:	↑0.08 € m^{-3}.	↑0.08 € m^{-3}.
in-field SAT:	↑0.08 € m^{-3}	↑0.08 € m^{-3}.

The change of S price in mineral fertilisers has same impact by different SATs and slurry types, except pig slurry with in-house SAT.

Table 37. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.055	1.87	2.02	**0.15**	2.00	1.91	**-0.09**	2.12	1.88	**-0.24**
0.088	1.84	2.02	**0.18**	1.97	1.91	**-0.06**	2.10	1.88	**-0.22**
0.11	1.83	2.02	**0.19**	1.96	1.91	**-0.05**	2.08	1.88	**-0.20**
0.132	1.81	2.02	**0.21**	1.94	1.91	**-0.03**	2.06	1.88	**-0.18**
0.165	1.78	2.02	**0.24**	1.91	1.91	**0.00**	2.03	1.88	**-0.15**

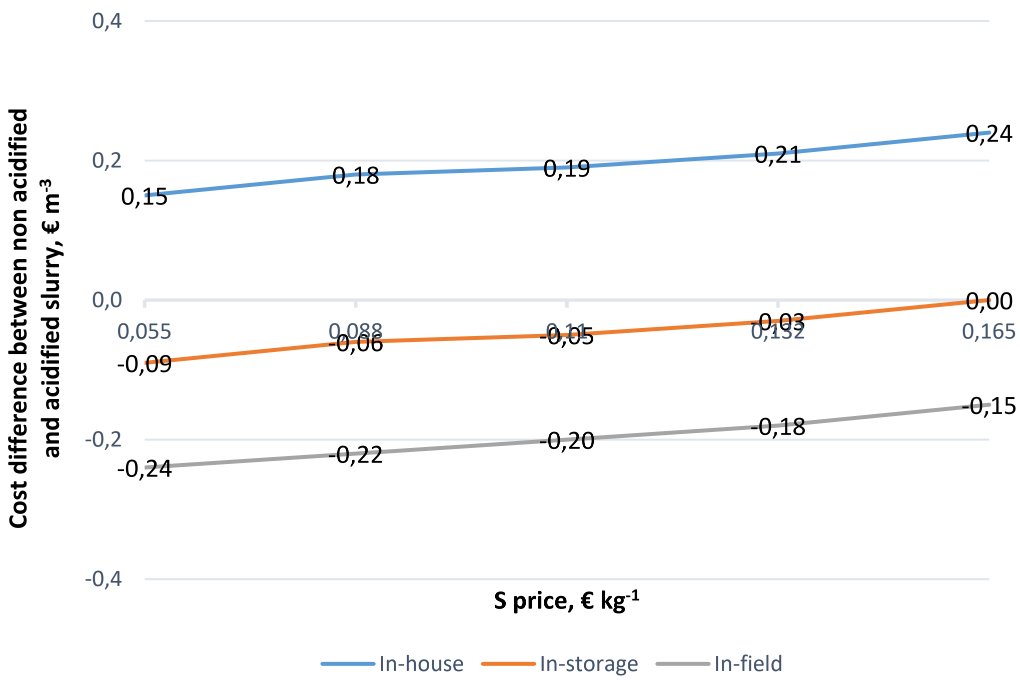

Figure 18. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

Table 38. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.055	1.42	2.40	**0.98**	1.76	1.95	**0.19**	1.95	1.91	**-0.04**
0.088	1.38	2.40	**1.02**	1.73	1.95	**0.22**	1.92	1.91	**-0.01**
0.11	1.36	2.40	**1.04**	1.71	1.95	**0.24**	1.90	1.91	**0.01**
0.132	1.34	2.40	**1.06**	1.69	1.95	**0.26**	1.88	1.91	**0.03**
0.165	1.30	2.40	**1.10**	1.67	1.95	**0.28**	1.86	1.91	**0.05**

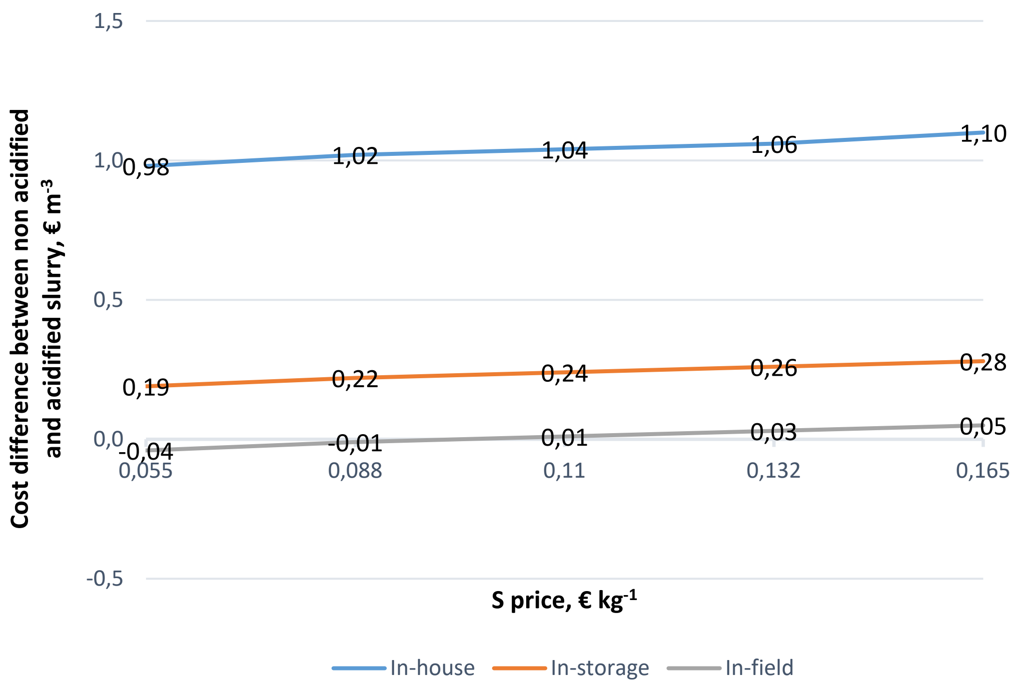

Figure 19. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

5.1.7. Summary, Belarus

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The in-house acidification has in Belarus significantly higher cost-benefit comapred to other SATs. The reason is that by in-house SAT is used bulk acid which is transported by big tank truck and has much lower price compared to the case if acid is transported in the IBC tanks, which is used by other SATs.

This is the reason why in-house acidification of cattle slurry has cost-benefit by annual amounts over 11,300 m^3, but no cost-benefit by other SATs. The acidification of pig slurry has cost-benefit by all SATs by bigger slurry amounts (about 5,300–24,000 m^3 ssslurry yearly , see Table 26).

Acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save
2) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry
3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower)

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The higher is the acid price, the bigger is the impact of acid amount on total costs of slurry acidification. The cattle slurry in-storage and in-field acidification would have cost-benefit if acid amount would be less than 3.5 and 2.5 litre per cubicmeter of slurry correspondigly.

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) decreases if acid content in slurry rises. Acid content change in slurry has lowest impact by in-house SAT and biggest by in-field SAT. The reason is that the acid price for in-house SAT is significantly lower (30 € t^{-1}) than by other SATs (101 € t^{-1}).

The calculations in paragraph 5.1 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts (Figure 50) show that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1} .

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount reaches the demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount per hectare and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 10 and 11 show also that the order of cover types is same for both, cattle and big slurries.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises. The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises. The change of S price in mineral fertilisers has same impact by different SATs and slurry types, except bigger difference by pig slurry with in-house SAT.

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system. The analysis model will be available on project website.

5.2.Denmark

5.2.1. Annual slurry amount, Denmark

Analysed is the cost-benefit of acidified slurry compared to non-acidified slurry if they both are band-spreaded, but the non acidified slurry is

A) not incorporated after band-application or

B) incorporated by disc-harrow <12 h after band-application.

The acid price in the calculations is 128 € t^{-1} for in-house acidification and 157 € t^{-1} for in-storage and in-field acidification. N-fertilisers is AN34.4, 345 € t^{-1}. NS-fertiliser N21-S24, 366 € t^{-1}. Thus N price 1 € kg^{-1} and S price 0,65 € kg^{-1}.

The results show that by both incorporation scenarios of non-acidified slurry, the slurry acidification has cost-benefit compared to non-acidification. The reason for high cost-benefits is relatively high price of mineral N and S (1 and 0,65 € kg^{-1}) compared to other countries (0.48-0.79 and 0.11-0.41 € kg^{-1}). However the cost-benefit by scenario A was 0.87-1,26 € kg^{-1} lower than in scenario B, because of smaller tillage cost (50 € ha^{-1}).

Table 39. The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit. The both types of slurry are applyed to the field by bandspreader without incorporation after application.

SAT	Dairy cows		Fatteners	
	Annual slurry amount, m^3	Number of animal	Annual slurry amount, m^3	Number of animal per year
In-house	9,384	391	4,846	9,691
In-storage	3,528	147	2,012	4,024
In-field	10,944	456	7,293	14,585

Table 39a. The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit. Analysed is the cost-benefit of acidified slurry compared to non-acidified slurry if they both are band-spreaded, but the no- acidified slurry is incorporated by disc-harrow <12 h after band-application .

SAT	Dairy cows		Fatteners	
	Annual slurry amount, m^3	Number of animal	Annual slurry amount, m^3	Number of animal per year
In-house	3,072	128	3,302	6,603
In-storage	1,296	54	1,124	2,248
In-field	3,720	155	3,328	6,657

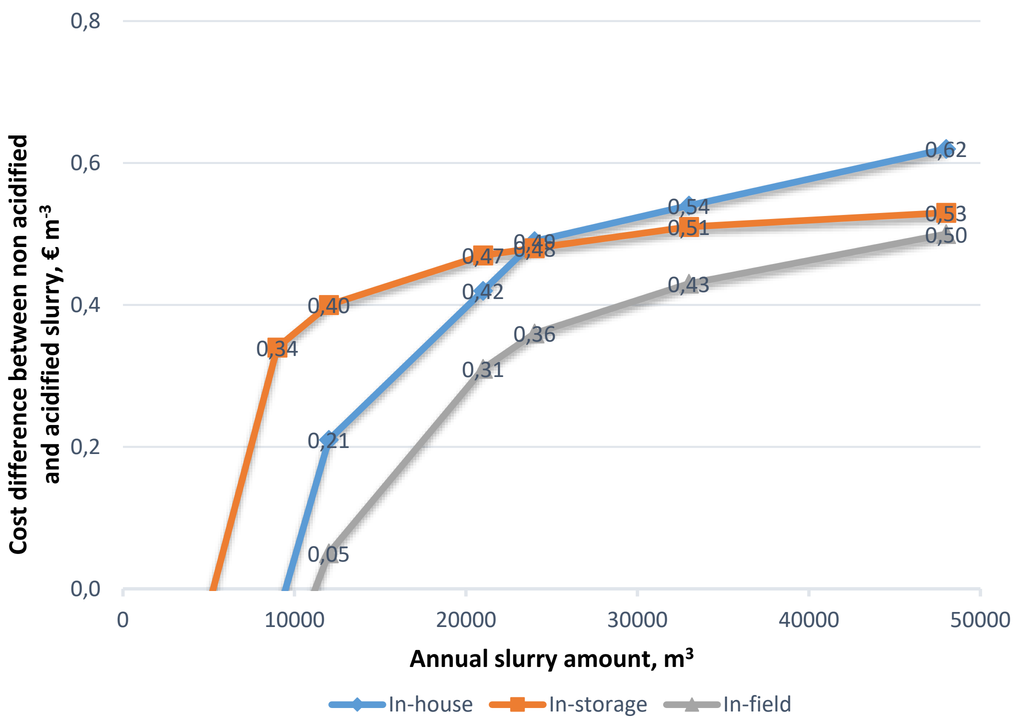

Figure 20. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to use of non-acidified slurry. The both types of slurry are applyed to the field by bandspreader without incorporation after application.

Table 40. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry..

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1,200	10.93	7.22	**-3.71**	7.36	7.18	**-0.18**	11.52	7.17	**-4.35**
2,400	6.66	6.00	**-0.66**	5.04	5.96	**0.92**	7.07	5.95	**-1.12**
9,000	3.03	4.23	**1.20**	2.59	4.19	**1.60**	3.06	4.18	**1.12**
12,000	2.50	3.92	**1.42**	2.26	3.88	**1.62**	2.59	3.87	**1.28**
21,000	1.84	3.38	**1.54**	1.74	3.34	**1.60**	1.89	3.33	**1.44**
24,000	1.69	3.27	**1.58**	1.63	3.23	**1.60**	1.75	3.21	**1.46**
33,000	1.43	3.00	**1.57**	1.41	2.97	**1.56**	1.48	2.95	**1.47**
48,000	1.15	2.72	**1.57**	1.19	2.69	**1.50**	1.21	2.67	**1.46**

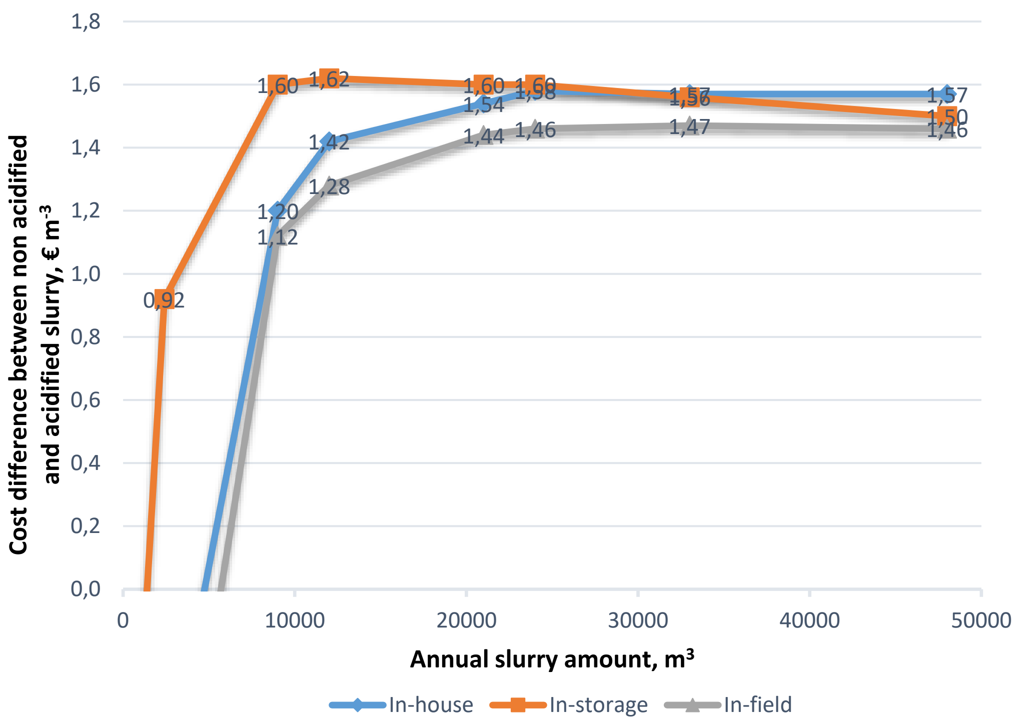

Figure 21. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

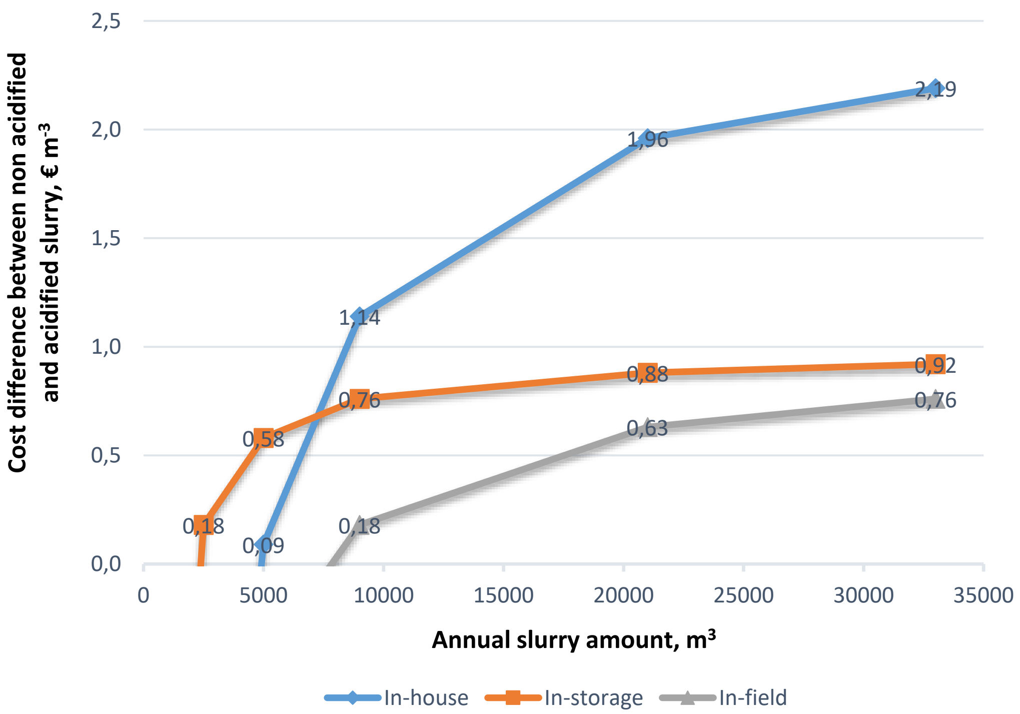

Figure 22. The cost decrease (€ m^{-3}) by use of fatteners slurry acidification compared to use of non-acidified slurry. The both types of slurry are applyed to the field by bandspreader without incorporation after application.

Table 41. Fattener slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
500	33.39	9.27	**-24.12**	12.00	9.10	**-2.90**	22.24	9.08	**-13.16**
2,500	7.45	6.08	**-1.37**	4.62	5.91	**1.29**	6.65	5.89	**-0.76**
5,000	3.66	5.08	**1.42**	3.15	4.91	**1.76**	4.15	4.90	**0.75**
9,000	1.91	4.37	**2.46**	2.28	4.20	**1.92**	2.84	4.18	**1.34**
21,000	0.37	3.52	**3.15**	1.43	3.35	**1.92**	1.66	3.34	**1.68**
33,000	-0.15	3.15	**3.30**	1.10	2.98	**1.88**	1.25	2.96	**1.71**

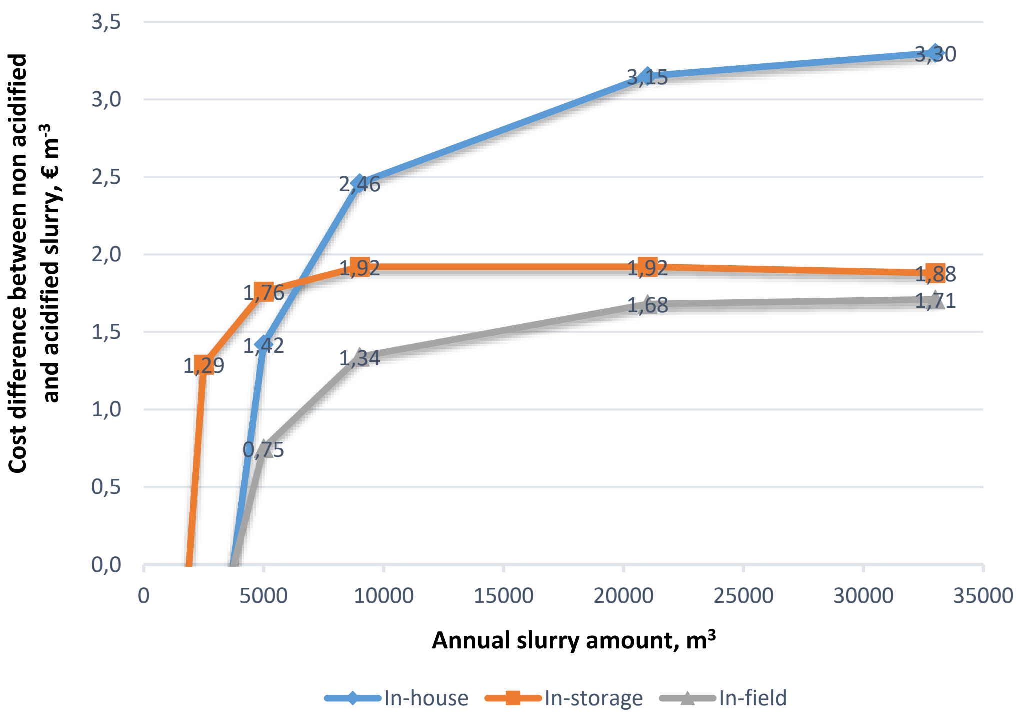

Figure 23. The cost decrease (€ m^{-3}) by use of fattener slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

5.2.2. Cover type, Denmark

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 24 and 25 show also that the order of cover types is same for both, cattle and big slurries.

The required minimum manure storage capacity in Denmark is 9 months as a general rule. In this analysis is presumed that animal are housed in all year around and storage depth is 5 m. The capital cost of slurry storage cover calculated for these conditions are shown in the table 21.

For Denmark, analysed was the cost-benefit of slurry acidification, compared to non-acidified slurry which is stored under cover but not incorparated after band-application (figures 25 and 27; tables 43 and 45). The results show that in this case the cost-benefit decreases compared to the case if slurry is covered and incorporated both.

Table 42. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3. Analysed is the cost-benefit of acidified slurry compared to non-acidified slurry if they both are band-spreaded, but the no-acidified slurry is incorporated by disc-harrow <12 h after band-application .

Cover type	In-house Acid	 No acid	 **Dif.**
No cover	1.84	3.38	**1.54**
Chopped straw	2.11	3.47	**1.36**
Fibo clay balls (fraction 10-20 mm)	2.17	3.51	**1.34**
Floating foil	2.19	3.53	**1.34**
Hexa-cover plates	2.21	3.54	**1.33**
Peat	2.19	3.85	**1.66**
Rapeseed oil	2.17	4.49	**2.32**
Tent cover	2.23	3.94	**1.71**

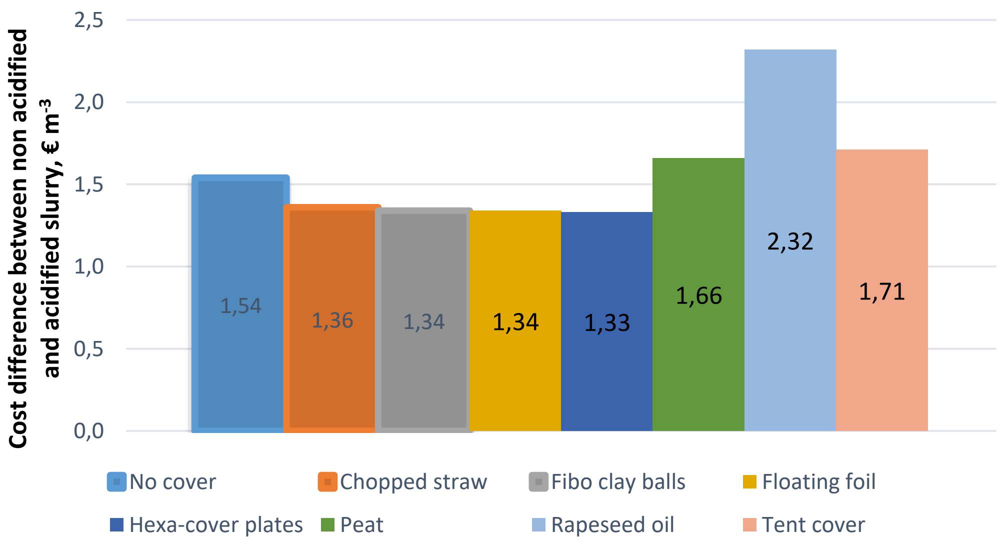

Figure 24. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3. Analysed is the cost-benefit of acidified slurry compared to non-acidified slurry if they both are band-spreaded, but the no-acidified slurry is incorporated by disc-harrow <12 h after band-application .

Table 43. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3. The both types of slurry are applied to the field by bandspreader without incorporation after application.

	In-house		
Cover type	Acid	No acid	**Dif.**
No cover	1.32	1.74	**0.42**
Chopped straw	1.55	1.83	**0.28**
Fibo clay balls (fraction 10-20 mm)	1.60	1.87	**0.27**
Floating foil	1.62	1.89	**0.27**
Hexa-cover plates	1.64	1.90	**0.26**
Peat	1.62	2.22	**0.60**
Rapeseed oil	1.60	2.85	**1.25**
Tent cover	1.65	2.30	**0.65**

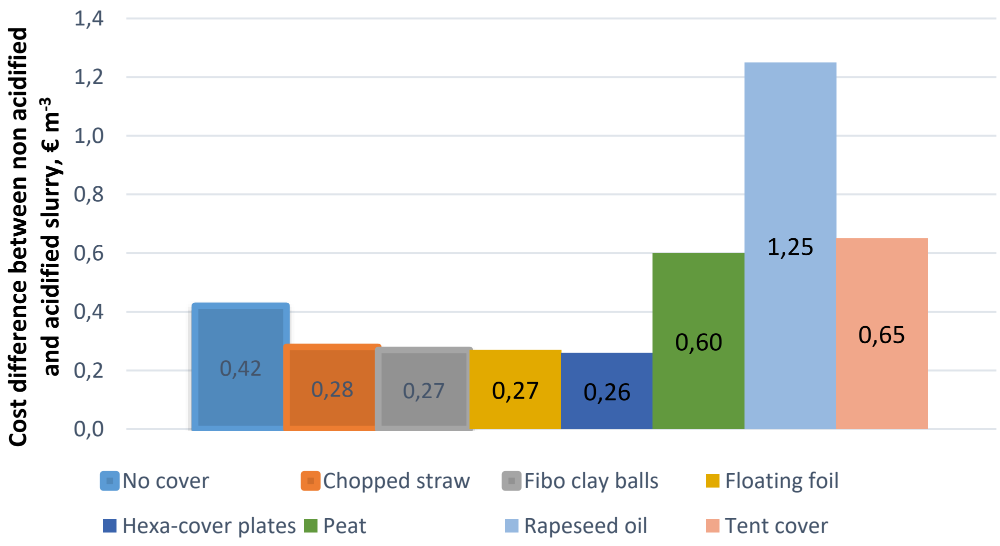

Figure 25. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3. The both types of slurry are applied to the field by bandspreader without incorporation after application.

Table 44. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^{3}. Analysed is the cost-benefit of acidified slurry compared to non-acidified slurry if they both are band-spreaded, but the no-acidified slurry is incorporated by disc-harrow <12 h after band-application .

Cover type	Acid	In-house No acid	**Dif.**
No cover	0.37	3.52	**3.15**
Chopped straw	0.70	3.61	**2.91**
Fibo clay balls (fraction 10-20 mm)	0.78	3.64	**2.86**
Floating foil	0.80	3.66	**2.86**
Hexa-cover plates	0.83	3.67	**2.84**
Peat	0.80	3.99	**3.19**
Rapeseed oil	0.78	4.62	**3.84**
Tent cover	0.85	4.07	**3.22**

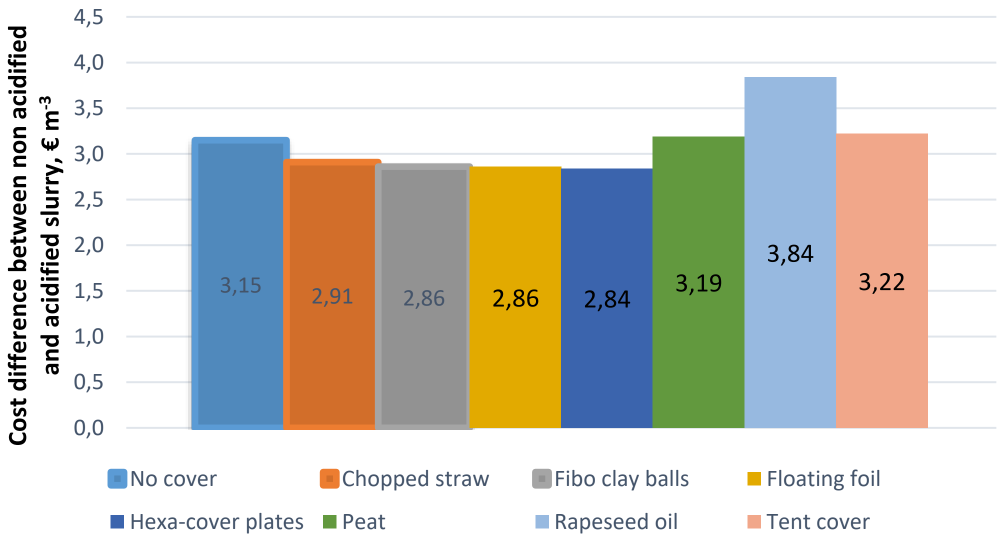

Figure 26. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners. Analysed is the cost-benefit of acidified slurry compared to non-acidified slurry if they both are band-spreaded, but the no- acidified slurry is incorporated by disc-harrow <12 h after band-application .

Table 45. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual

slurry amount 21,000 m^3. The both types of slurry are applied to the field by bandspreader without incorporation after application.

Cover type	In-house Acid	In-house No acid	**Dif.**
No cover	-0.09	1.87	**1.96**
Chopped straw	0.20	1.96	**1.76**
Fibo clay balls (fraction 10-20 mm)	0.27	2.00	**1.73**
Floating foil	0.29	2.02	**1.73**
Hexa-cover plates	0.31	2.03	**1.72**
Peat	0.29	2.34	**2.05**
Rapeseed oil	0.27	2.98	**2.71**
Tent cover	0.33	2.43	**2.10**

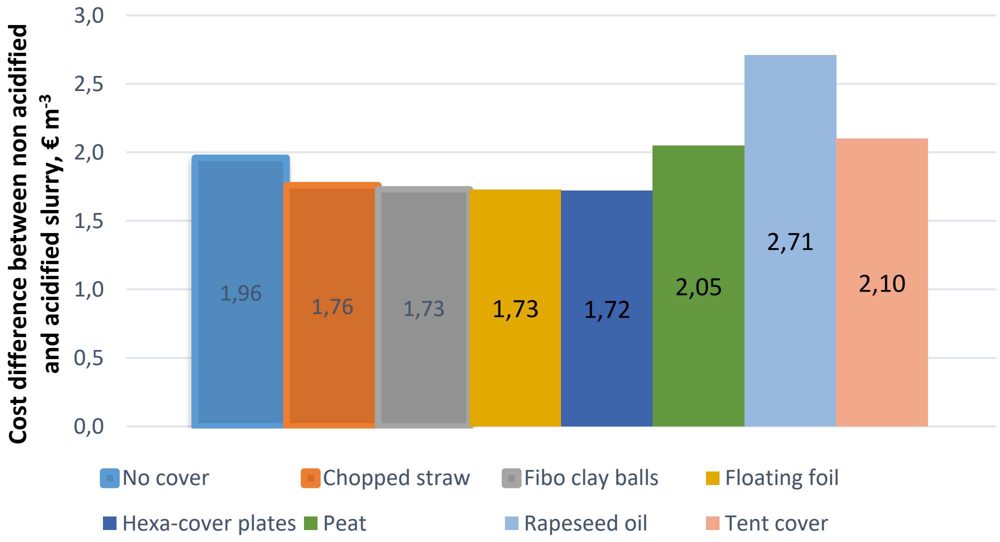

Figure 27. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners. The both types of slurry are applyed to the field by bandspreader without incorporation after application.

5.2.3. Acid consumption, Denmark

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) decreases if acid amount per cubicmeter increases.

If acid consumption ↑ 1 l m^{-3}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↓0.26 € m^{-3}	↓0.24 € m^{-3}
in-storage SAT:	↓0.33 € m^{-3}	↓0.33 € m^{-3}
in-field SAT:	↓0.35 € m^{-3}	↓0.34 € m^{-3}

Acid content change in slurry has lowest impact by in-house SAT and biggest by in-field SAT. The reason is that the acid price for in-house SAT is lower (128 € t^{-1}) than by other SATs (157 € t^{-1}).

Table 46. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount	In-house			In-storage			In-field		
l m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	1.00	3.38	**2.38**	1.00	3.34	**2.34**	1.24	3.33	**2.09**
3	1.40	3.38	**1.98**	1.52	3.34	**1.82**	1.89	3.33	**1.44**
4	1.70	3.38	**1.68**	1.88	3.34	**1.46**	2.25	3.33	**1.08**
5	1.99	3.38	**1.39**	2.24	3.34	**1.10**	2.61	3.33	**0.72**
7	2.58	3.38	**0.80**	2.95	3.34	**0.39**	3.34	3.33	**-0.01**

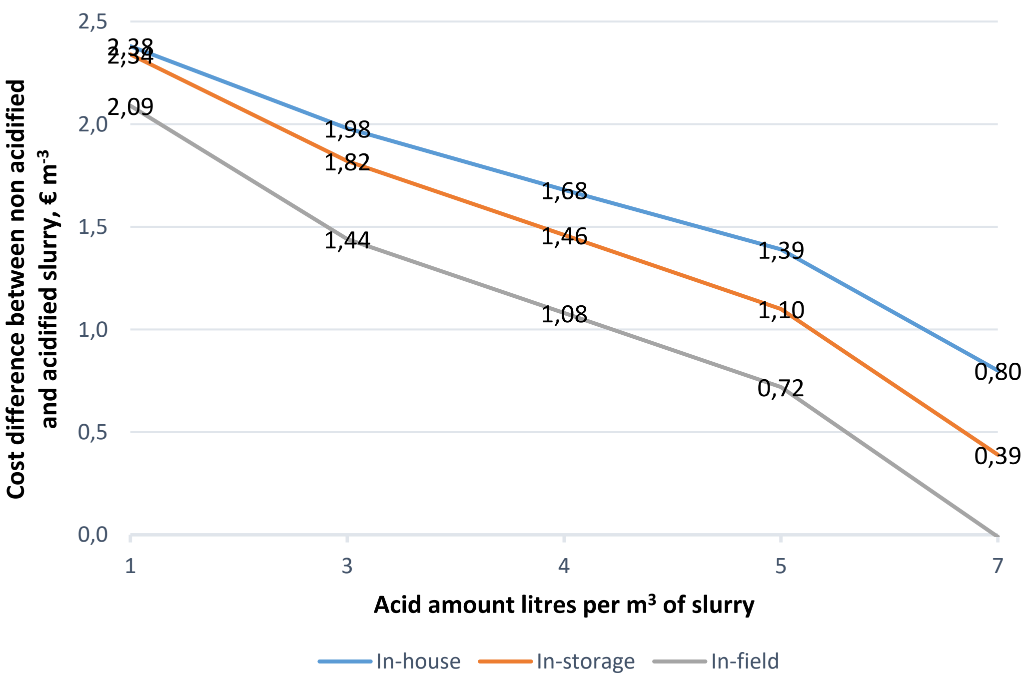

Figure 28. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

Table 47. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount	In-house			In-storage			In-field		
l m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	-0.02	3.52	**3.54**	0.90	3.35	**2.45**	1.26	3.34	**2.08**
3	0.22	3.52	**3.30**	1.43	3.35	**1.92**	1.81	3.34	**1.53**

4	0.51	3.52	**3.01**	1.78	3.35	**1.57**	2.17	3.34	**1.17**
5	0.80	3.52	**2.72**	2.14	3.35	**1.21**	2.54	3.34	**0.80**
7	1.39	3.52	**2.13**	2.85	3.35	**0.50**	3.27	3.34	**0.07**

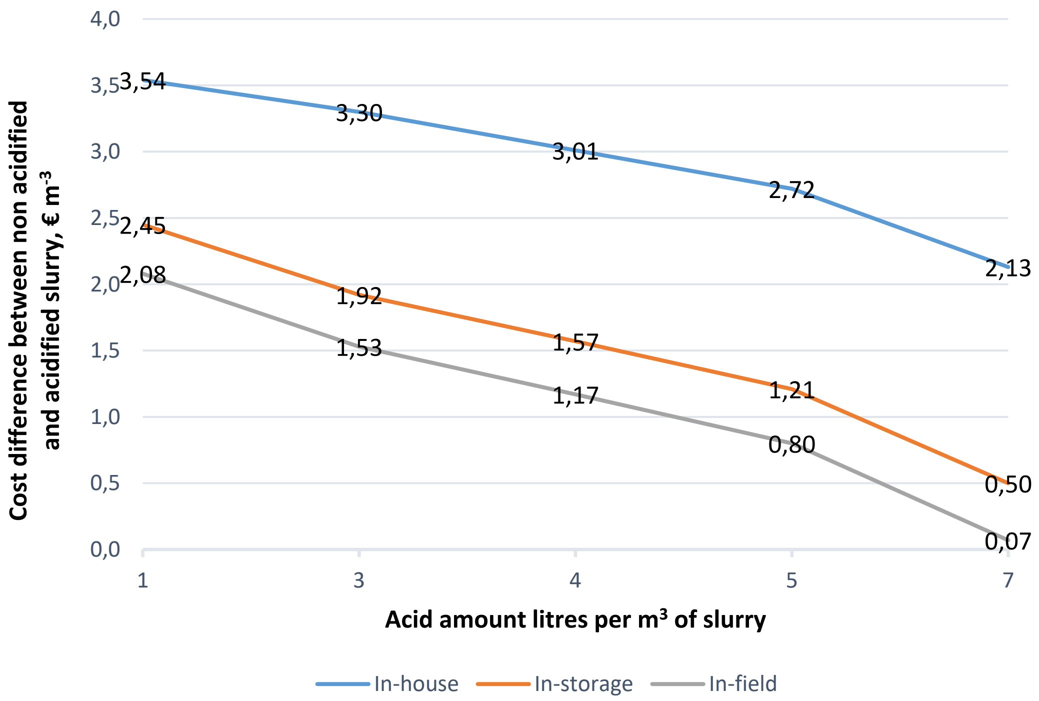

Figure 29. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

5.2.4. N_{tot} in slurry, Denmark

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

If N_{tot} content in slurry ↑ 1 kg m^{-3} , then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.18 € m^{-3}.	↑0.36 € m^{-3}.
in-storage SAT:	↑0.14 € m^{-3}.	↑0.15 € m^{-3}.
in-field SAT:	↑0.11 € m^{-3}	↑0.12 € m^{-3}.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.

Table 48. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m-3	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
3				1.96	3.32	**1.36**	2.06	3.31	**1.25**
4	2.15	3.35	**1.20**	1.83	3.33	**1.50**	1.96	3.32	**1.36**
5	1.99	3.37	**1.38**	1.70	3.35	**1.65**	1.86	3.33	**1.47**
6	1.83	3.38	**1.55**	1.58	3.36	**1.78**	1.76	3.34	**1.58**
7	1.67	3.40	**1.73**						

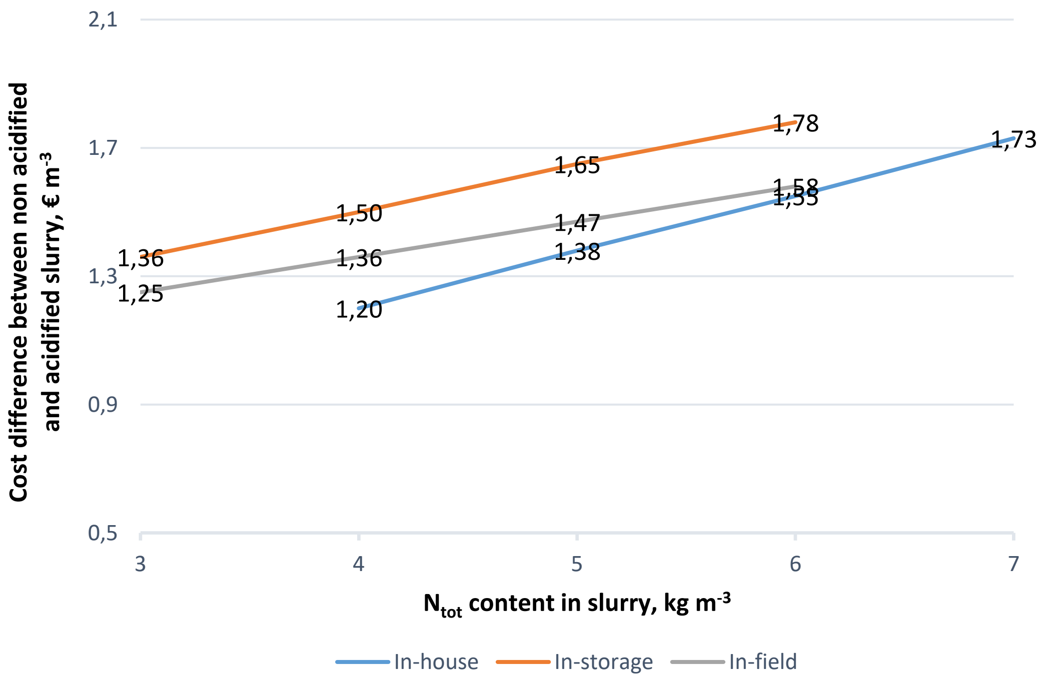

Figure 30. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Table 49. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m-3	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
4	-	-		1.62	3.33	**1.71**	1.82	3.32	**1.50**
5	1.02	3.45	**2.43**	1.49	3.35	**1.86**	1.71	3.33	**1.62**
6	0.69	3.49	**2.80**	1.36	3.36	**2.00**	1.61	3.34	**1.73**
7	0.37	3.52	**3.15**	1.23	3.38	**2.15**	1.51	3.36	**1.85**
8	0.04	3.56	**3.52**	-	-		-	-	

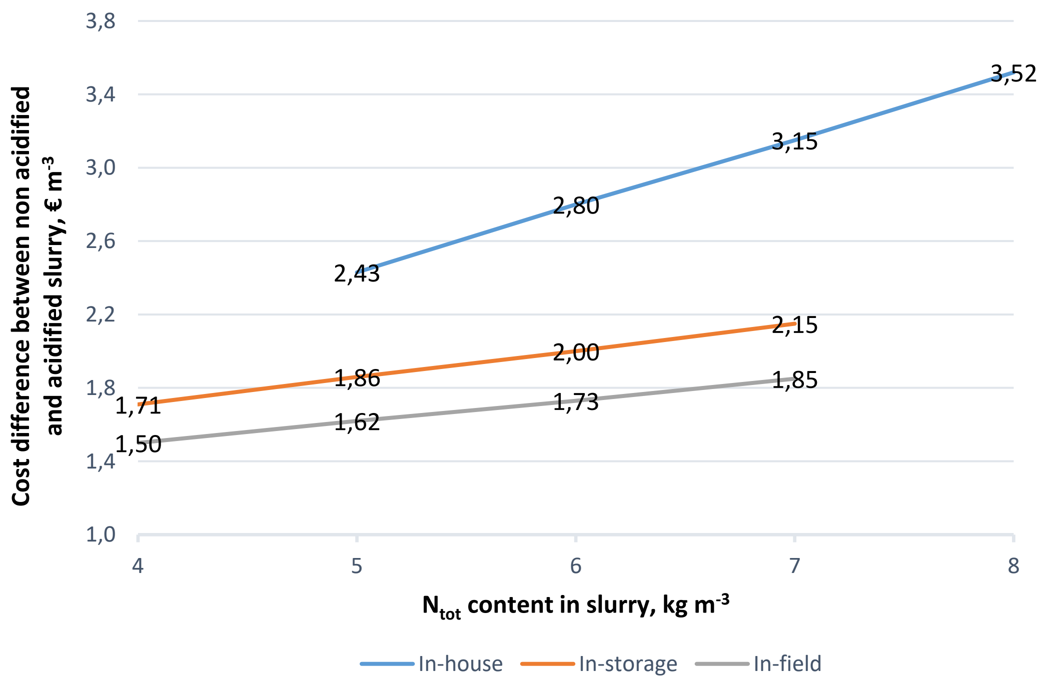

Figure 31. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

5.2.5. N price, Denmark

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

N price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.089 € m^{-3}.	↑0.21 € m^{-3}.
in-storage SAT:	↑0.057 € m^{-3}.	↑0.07 € m^{-3}.
in-field SAT:	↑0.045 € m^{-3}	↑0.05 € m^{-3}.

The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.
Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

Table 50. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.5	2.29	3.38	**1.09**	2.02	3.34	**1.32**	2.11	3.33	**1.22**

0.8	2.02	3.38	**1.36**	1.85	3.34	**1.49**	1.98	3.33	**1.35**
1	1.84	3.38	**1.54**	1.74	3.34	**1.60**	1.88	3.33	**1.45**
1.2	1.67	3.38	**1.71**	1.62	3.34	**1.72**	1.79	3.33	**1.54**
1.5	1.40	3.38	**1.98**	1.45	3.34	**1.89**	1.66	3.33	**1.67**

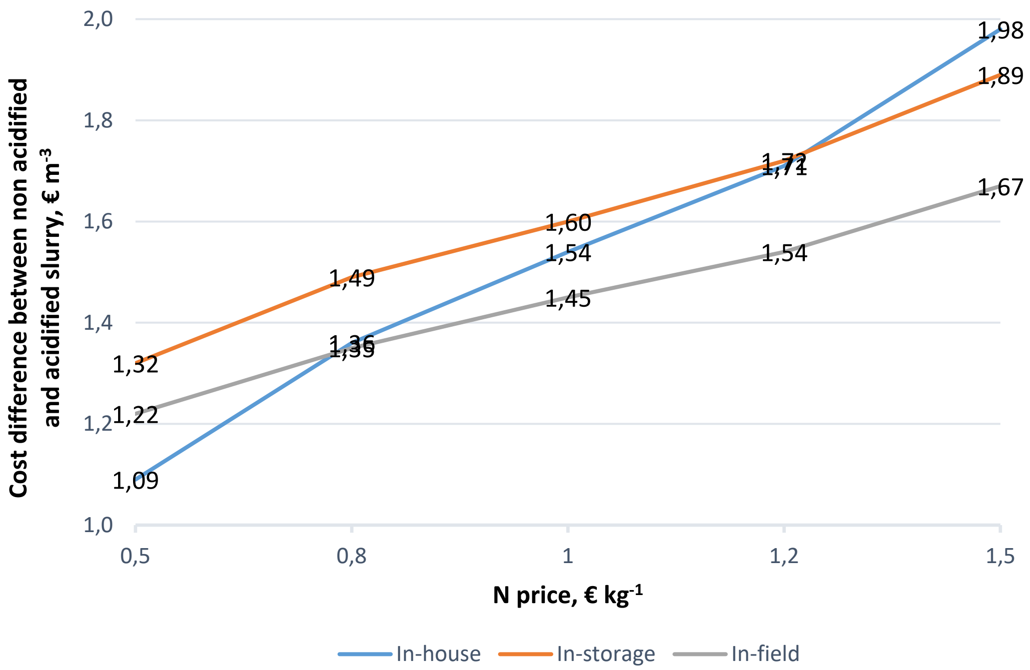

Figure 32. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

Table 51. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.5	1.43	3.52	**2.09**	1.76	3.35	**1.59**	1.93	3.34	**1.41**
0.8	0.79	3.52	**2.73**	1.56	3.35	**1.79**	1.77	3.34	**1.57**
1	0.37	3.52	**3.15**	1.43	3.35	**1.92**	1.66	3.34	**1.68**
1.2	-0.06	3.52	**3.58**	1.29	3.35	**2.06**	1.56	3.34	**1.78**
1.5	-0.69	3.52	**4.21**	1.10	3.35	**2.25**	1.40	3.34	**1.94**

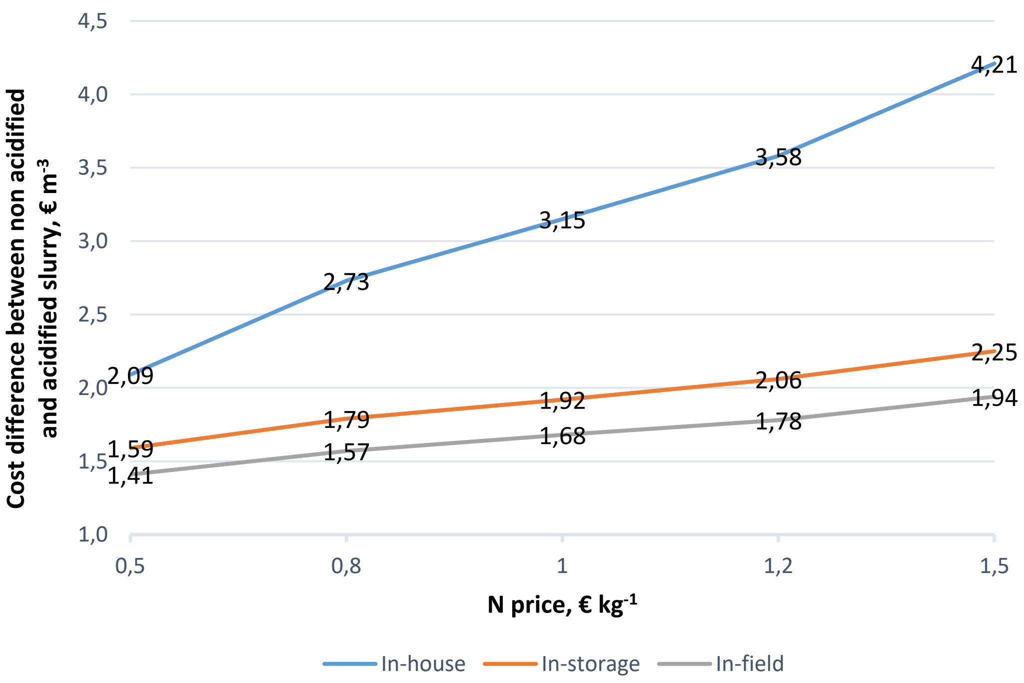

Figure 33. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

5.2.6. S price, Denmark

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

S price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.08 € m^{-3}.	↑0.10 € m^{-3}.
in-storage SAT:	↑0.08 € m^{-3}.	↑0.08 € m^{-3}.
in-field SAT:	↑0.08 € m^{-3}	↑0.08 € m^{-3}.

The change of S price in mineral fertilisers has same impact by different SATs and slurry types, except pig slurry with in-house SAT.

Table 52. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.325	2.12	3.38	**1.26**	2.01	3.34	**1.33**	2.11	3.33	**1.22**
0.52	1.95	3.38	**1.43**	1.85	3.34	**1.49**	1.99	3.33	**1.34**
0.65	1.84	3.38	**1.54**	1.74	3.34	**1.60**	1.88	3.33	**1.45**
0.78	1.74	3.38	**1.64**	1.63	3.34	**1.71**	1.78	3.33	**1.55**
0.975	1.57	3.38	**1.81**	1.47	3.34	**1.87**	1.61	3.33	**1.72**

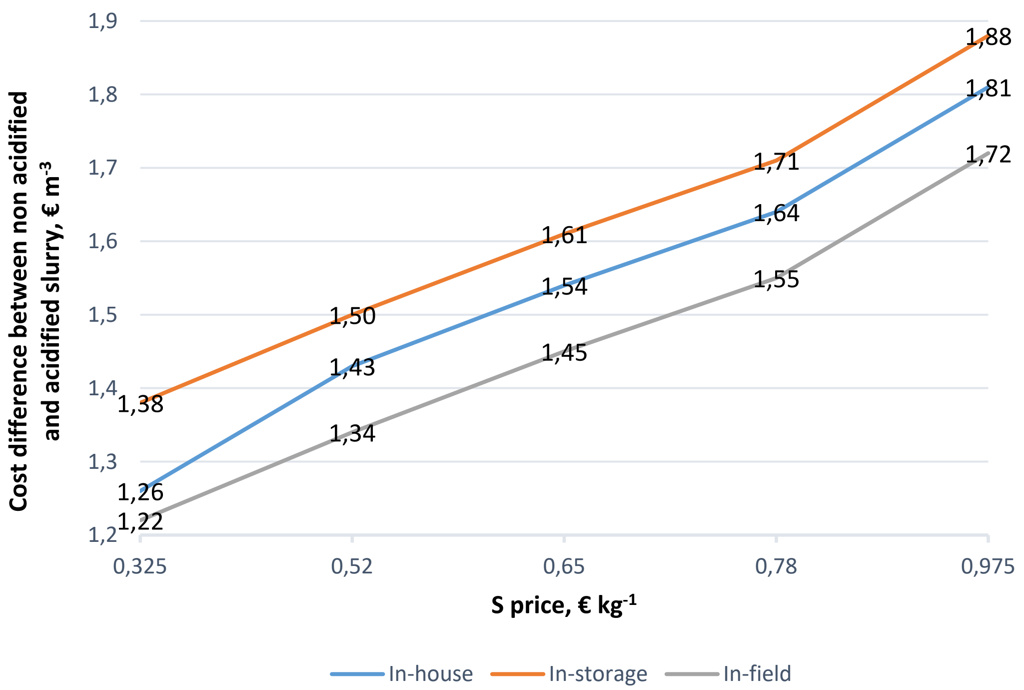

Figure 34. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

Table 53. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.325	0.66	3.52	**2.86**	1.70	3.35	**1.65**	1.89	3.34	**1.45**
0.52	0.50	3.52	**3.02**	1.53	3.35	**1.82**	1.77	3.34	**1.57**
0.65	0.37	3.52	**3.15**	1.43	3.35	**1.92**	1.66	3.34	**1.68**
0.78	0.23	3.52	**3.29**	1.32	3.35	**2.03**	1.55	3.34	**1.79**
0.975	0.03	3.52	**3.49**	1.16	3.35	**2.19**	1.39	3.34	**1.95**

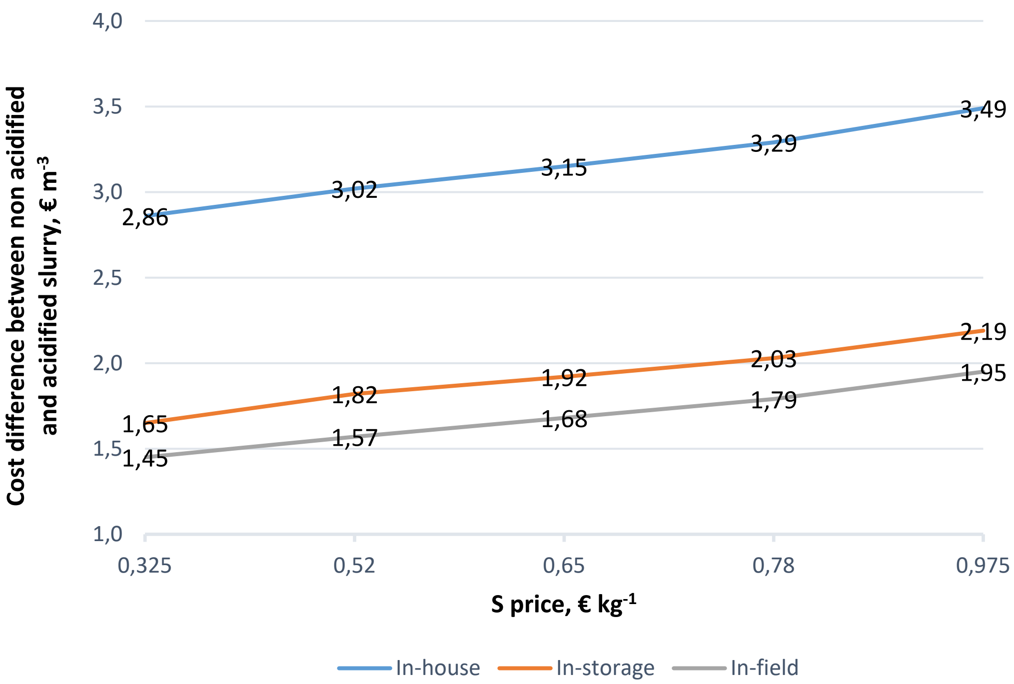

Figure 35. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

5.2.7. Summary, Denmark

For Denmark, analysed is the cost-benefit of acidified slurry compared to non-acidified slurry if they both are band-spreaded, but the non-acidified slurry is

A) not incorporated after band-application or
B) incorporated by disc-harrow <12 h after band-application.

The results show that by both incorporation scenarios of non-acidified slurry, the slurry acidification has cost-benefit compared to non-acidification. The reason for high cost-benefits is relatively high price of mineral N and S (1 and 0.65 € kg^{-1}) compared to other countries (0.48–0.79 and 0.11–0.41 € kg^{-1}). However, the cost-benefit by scenario A was 0.87–1.26 € kg^{-1} lower than in scenario B, because of smaller tillage cost (50 € ha^{-1}).

The minimal slurry amounts should be between 1,300–3,700 and 2,200–6,700 m^3 yearly for cattle and pig slurry correspondingly, depending on SAT if slurry incorporated by disc-harrow <12 h after band-application (table 39a). And if slurry is not incorporated after band-application, then are these amounts 3,500–11,000 and 2,000–7,300 m^3 yearly (table 39).

Acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save

2) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry
3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower)

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) decreases if acid amount per cubicmeter increases. While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The acid price by in-house SAT (128 € m^{-3}) is lower than by other SATs (157 € m^{-3}) and this is the reason why change of acid amount has smaller effect on cost-benefit by first SAT compared to others.

The calculations in paragraph 5.2 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts (Figure 50) show that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1} .

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount reaches the demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount per hectare and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 24 and 25 show also that the order of cover types is same for both, cattle and big slurries.

For Denmark, analysed was the cost-benefit of slurry acidification, compared to non-acidified slurry which is stored under cover but not incorparated after band-application (figures 25 and 27; tables 43 and 45). The results show that in this case the cost-benefit decreases compared to the case if slurry is covered and incorporated both.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises (see 5.2.4). N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises (see 5.2.5).. The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises (see 5.2.6.). The change of S price in mineral fertilisers has same impact by different SATs and slurry types, except bigger difference by pig slurry with in-house SAT.

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system. The analysis model will be available on project website.

5.3. Estonia

5.3.1. Annual slurry amount, Estonia

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The acid price in the calculations is 127 € t^{-1} for in-house acidification and 150 € t^{-1} for in-storage and in-field acidification. Minimum storage period 8 month. N-fertilisers is AN34.4, 249 € t^{-1}. NS-fertiliser N21-S24, 205 € t^{-1}. Thus N price 0.72 € kg^{-1} and S price 0.24 € kg^{-1}. The prices of project partner countries are between 0.48–1 and 0.11–0.85€ kg^{-1} respectively.

All three SATs have cost- benefit by cattle and pig slurry both in Estonia. The minimal slurry amounts should be between 3,300–9,900 and 2,300–7,300 m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 54).

Table 54. The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit.

SAT	Dairy cows		Fatteners	
	Annual slurry amount, m^3	Number of animal	Annual slurry amount, m^3	Number of animal per year
In-house	9,408	392	5,448	10,896
In-storage	3,312	138	2,339	4,678
In-field	9,942	414	7,339	14,678

Table 55. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1,200	10.46	6.25	**-4.21**	7.57	6.21	**-1.36**	11.61	6.19	**-5.42**
2,400	6.51	4.93	**-1.58**	5.17	4.89	**-0.28**	7.13	4.88	**-2.25**
9,000	3.19	3.16	**-0.03**	2.73	3.12	**0.39**	3.17	3.10	**-0.07**
12,000	2.71	2.87	**0.16**	2.42	2.83	**0.41**	2.71	2.81	**0.10**
21,000	2.12	2.38	**0.26**	1.93	2.34	**0.41**	2.05	2.33	**0.28**
24,000	1.98	2.28	**0.30**	1.84	2.24	**0.40**	1.93	2.22	**0.29**
33,000	1.76	2.05	**0.29**	1.64	2.01	**0.37**	1.68	2.00	**0.32**
48,000	1.52	1.81	**0.29**	1.45	1.77	**0.32**	1.44	1.76	**0.32**

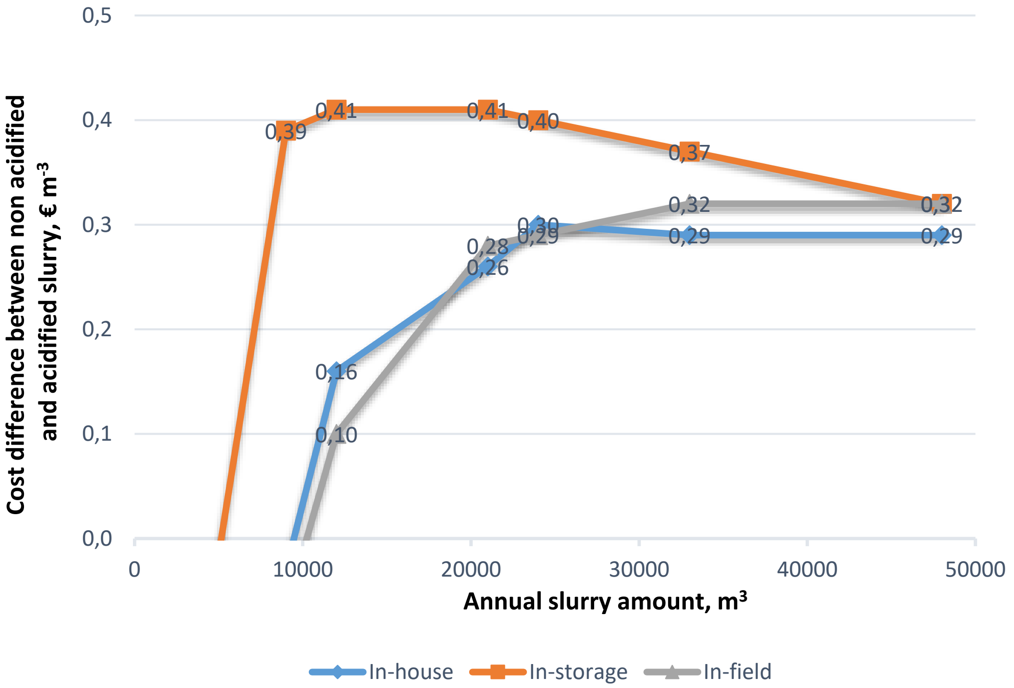

Figure 36. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Table 56. Fattener slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
500	32.57	8.57	**-24.00**	12.53	8.40	**-4.13**	22.50	8.39	**-14.11**
2,500	7.81	5.01	**-2.80**	4.77	4.84	**0.07**	6.72	4.82	**-1.90**
5,000	4.20	3.99	**-0.21**	3.28	3.82	**0.54**	4.24	3.81	**-0.43**
9,000	2.56	3.30	**0.74**	2.44	3.13	**0.69**	2.95	3.11	**0.16**
21,000	1.13	2.52	**1.39**	1.64	2.35	**0.71**	1.84	2.34	**0.50**
33,000	0.67	2.19	**1.52**	1.35	2.02	**0.67**	1.47	2.01	**0.54**

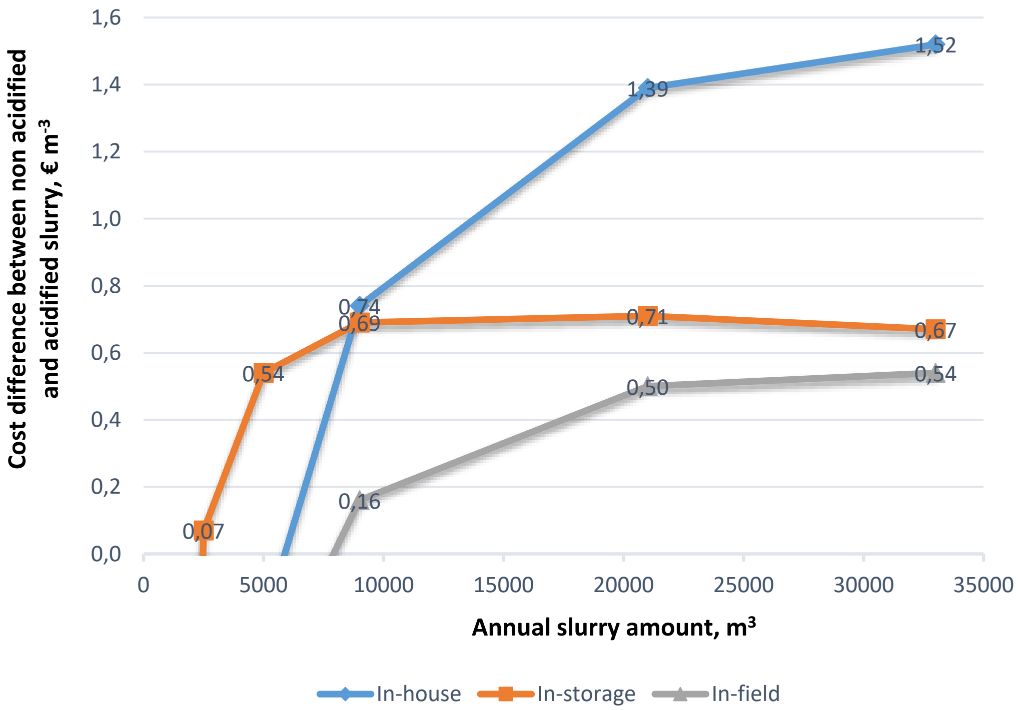

Figure 37. The cost decrease (€ m^{-3}) by use of fattener slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

5.3.2. Cover type, Estonia

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 38 and 39 show also that the order of cover types is same for both, cattle and big slurries.

In Estonia, the required minimum manure storage capacity is 8 months. In this analysis is presumed that animal are housed in all year around and storage depth is 5 m. The capital cost of slurry storage cover calculated for these conditions are shown in the table 21.

Table 57. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

	In-house		
Cover type	Acid	No acid	**Dif.**
No cover	2.12	2.38	**0.26**
Chopped straw	2.31	2.46	**0.15**
Fibo clay balls (fraction 10-20 mm)	2.35	2.49	**0.14**
Floating foil	2.37	2.50	**0.13**
Hexa-cover plates	2.38	2.52	**0.14**
Peat	2.37	2.79	**0.42**
Rapeseed oil	2.35	3.36	**1.01**
Tent cover	2.40	2.87	**0.47**

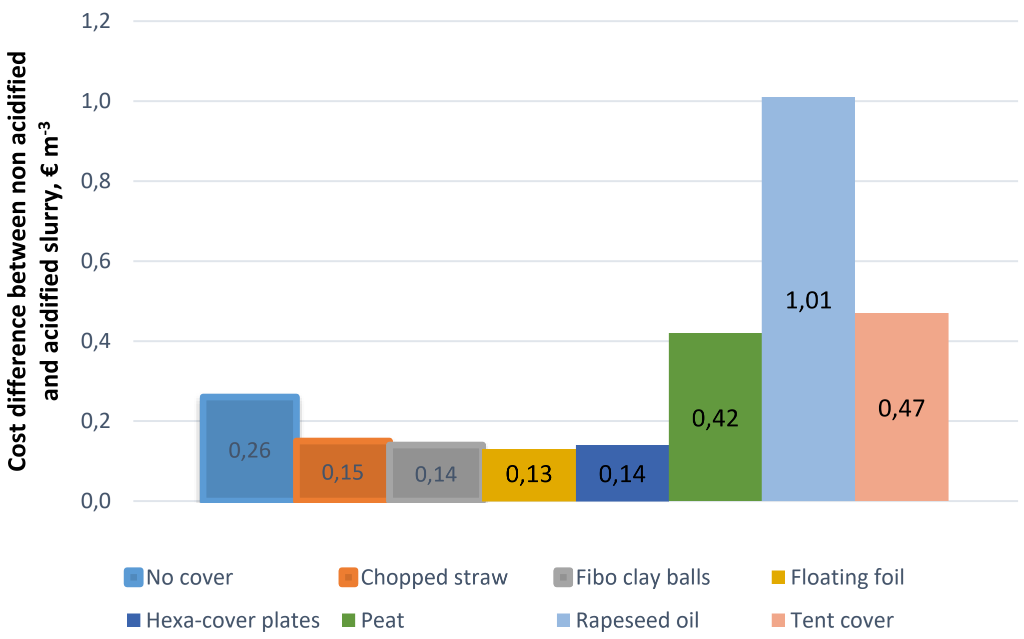

Figure 38. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Table 58. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	In-house Acid	No acid	**Dif.**
No cover	1.13	2.52	**1.39**
Chopped straw	1.37	2.59	**1.22**
Fibo clay balls (fraction 10-20 mm)	1.43	2.62	**1.19**
Floating foil	1.44	2.64	**1.20**
Hexa-cover plates	1.46	2.65	**1.19**
Peat	1.44	2.93	**1.49**
Rapeseed oil	1.43	3.49	**2.06**
Tent cover	1.48	3.00	**1.52**

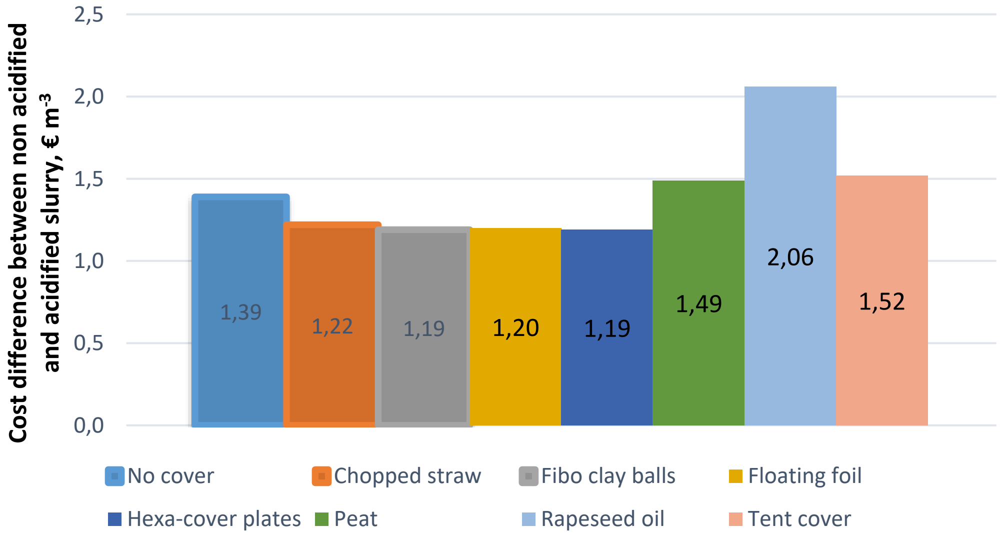

Figure 39. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners.

5.3.3. Acid consumption, Estonia

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) decreases if acid amount per cubicmeter increases.

If acid consumption ↑ 1 l m^{-3}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↓0.28 € m^{-3}	↓0.27 € m^{-3}
in-storage SAT:	↓0.33 € m^{-3}	↓0.32 € m^{-3}
in-field SAT:	↓0.34 € m^{-3}	↓0.34 € m^{-3}

Acid content change in slurry has lowest impact by in-house SAT and biggest by in-field SAT. The reason is that the acid price for in-house SAT is lower (127 € t^{-1}) than by other SATs (150 € t^{-1}).

Table 59. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house Acid	In-house No acid	In-house **Dif.**	In-storage Acid	In-storage No acid	In-storage **Dif.**	In-field Acid	In-field No acid	In-field **Dif**
1	1.18	2.38	**1.20**	1.13	2.34	**1.21**	1.44	2.33	**0.89**
3	1.69	2.38	**0.69**	1.73	2.34	**0.61**	2.05	2.33	**0.28**
4	1.98	2.38	**0.40**	2.07	2.34	**0.27**	2.40	2.33	**-0.07**
5	2.27	2.38	**0.11**	2.40	2.34	**-0.06**	2.75	2.33	**-0.42**
7	2.85	2.38	**-0.47**	3.08	2.34	**-0.74**	3.45	2.33	**-1.12**

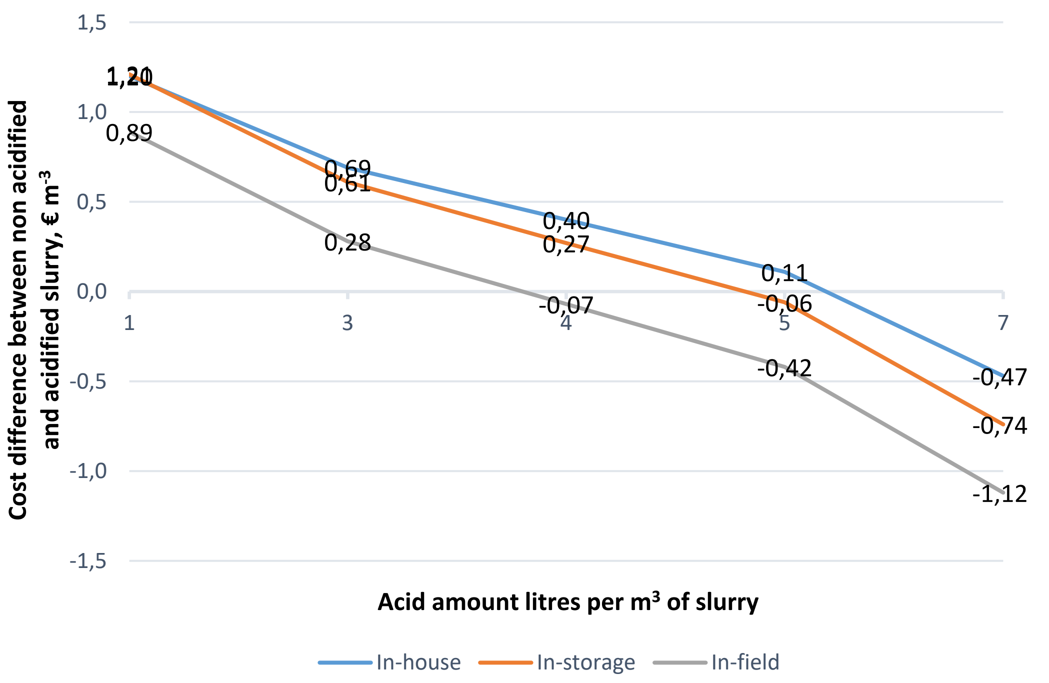

Figure 40. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

Table 60. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid	In-house	In-storage	In-field

amount l m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	0.54	2.52	**1.98**	1.04	2.35	**1.31**	1.34	2.34	**1.00**
3	0.99	2.52	**1.53**	1.64	2.35	**0.71**	1.98	2.34	**0.36**
4	1.28	2.52	**1.24**	1.97	2.35	**0.38**	2.33	2.34	**0.01**
5	1.57	2.52	**0.95**	2.31	2.35	**0.04**	2.68	2.34	**-0.34**
7	2.15	2.52	**0.37**	2.98	2.35	**-0.63**	3.37	2.34	**-1.03**

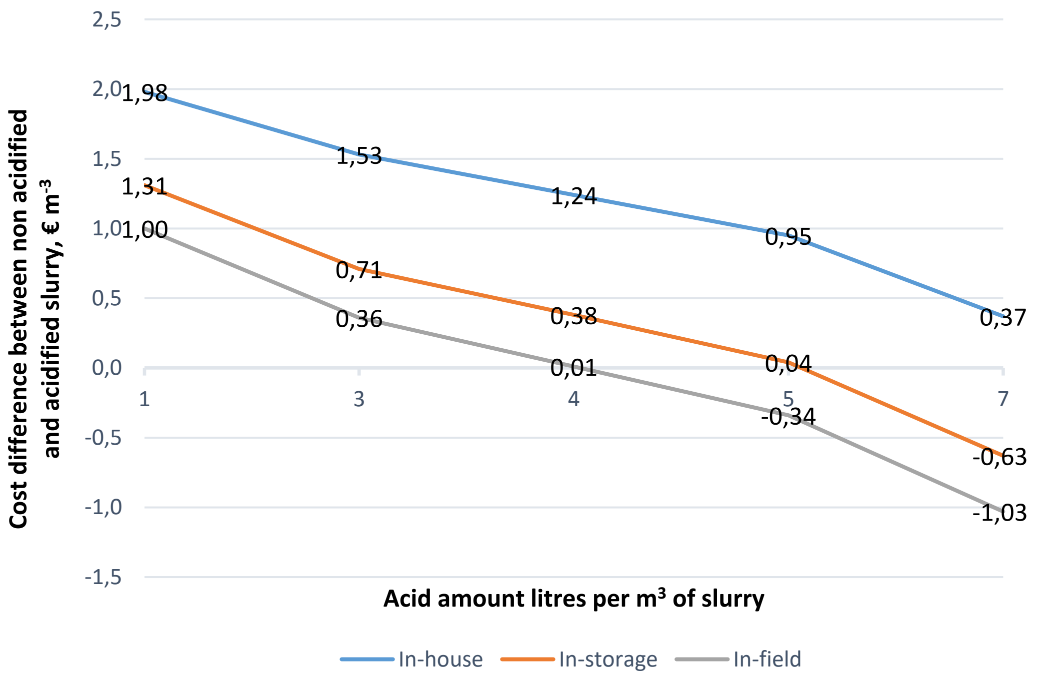

Figure 41. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

5.3.4. N_{tot} in slurry, Estonia

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

If N_{tot} content in slurry ↑ 1 kg m^{-3} , then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.13 € m^{-3}.	↑0.27 € m^{-3}.
in-storage SAT:	↑0.11 € m^{-3}.	↑0.10 € m^{-3}.
in-field SAT:	↑0.09 € m^{-3}	↑0.09 € m^{-3}.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.

Table 61. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
3				2.07	2.32	**0.25**	2.16	2.31	**0.15**
4	2.34	2.35	**0.01**	1.98	2.33	**0.35**	2.09	2.32	**0.23**
5	2.23	2.36	**0.13**	1.89	2.35	**0.46**	2.02	2.33	**0.31**
6	2.11	2.38	**0.27**	1.79	2.36	**0.57**	1.94	2.34	**0.40**
7	2.00	2.40	**0.40**						

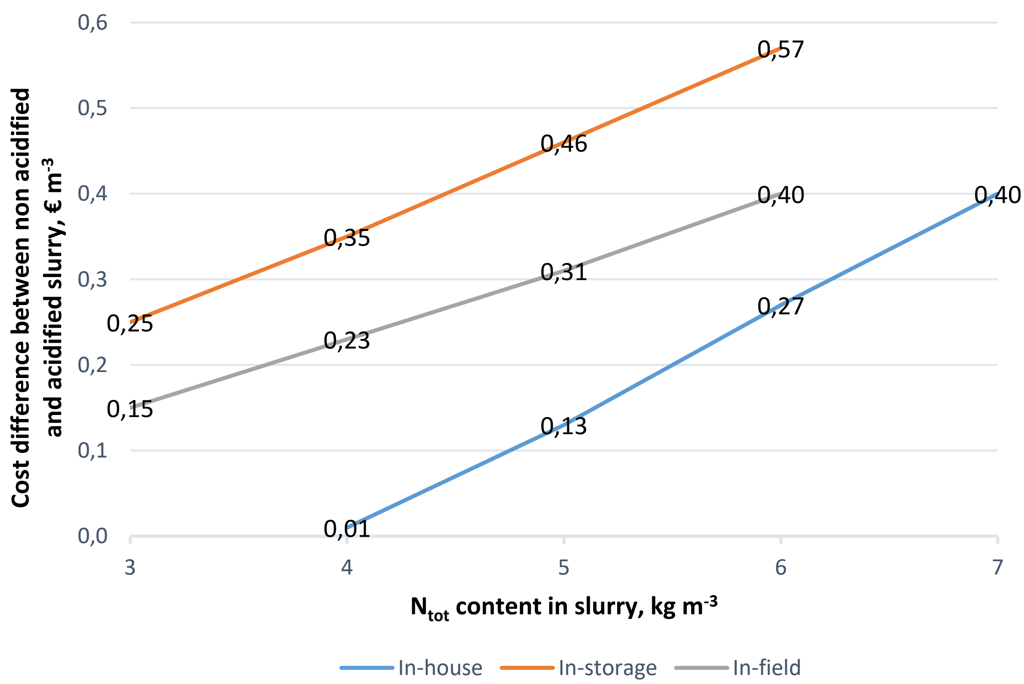

Figure 42. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Table 62. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
4				1.78	2.33	**0.55**	1.95	2.32	**0.37**
5	1.60	2.45	**0.85**	1.68	2.35	**0.67**	1.88	2.33	**0.45**
6	1.37	2.49	**1.12**	1.59	2.36	**0.77**	1.81	2.34	**0.53**
7	1.13	2.52	**1.39**	1.50	2.37	**0.87**	1.73	2.35	**0.62**
8	0.90	2.56	**1.66**						

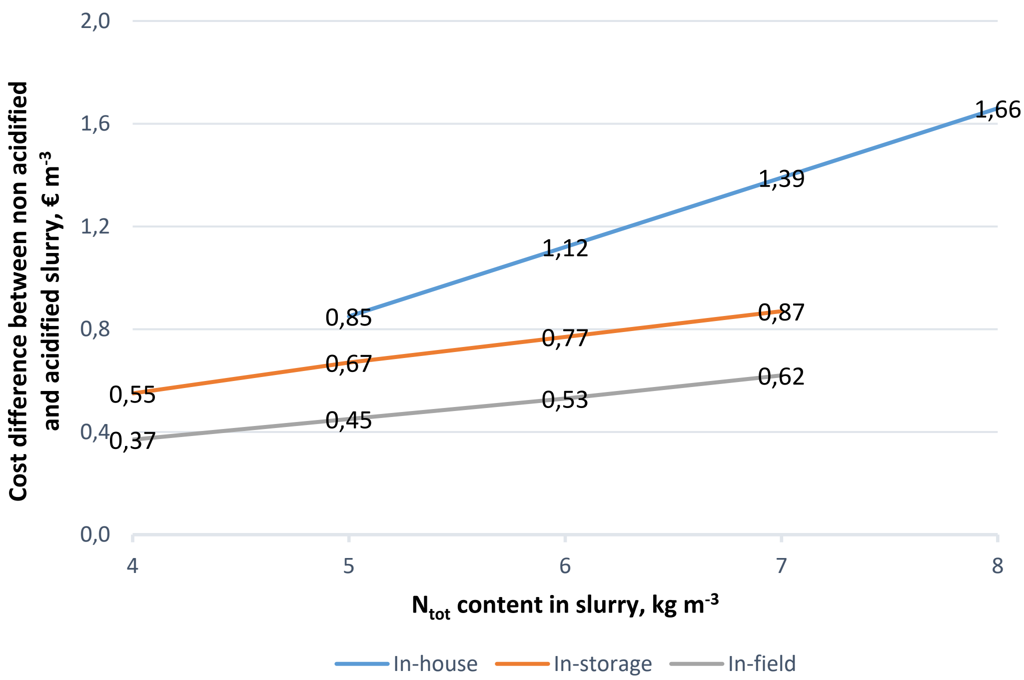

Figure 43. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

5.3.5. N price, Estonia

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

N price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.089 € m^{-3}.	↑0.21 € m^{-3}.
in-storage SAT:	↑0.054 € m^{-3}.	↑0.07 € m^{-3}.
in-field SAT:	↑0.043 € m^{-3}	↑0.05 € m^{-3}.

The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.
Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

Table 63. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.36	2.45	2.38	**-0.07**	2.13	2.34	**0.21**	2.21	2.33	**0.12**

0.576	2.25	2.38	**0.13**	2.01	2.34	**0.33**	2.12	2.33	**0.21**
0.72	2.13	2.38	**0.25**	1.93	2.34	**0.41**	2.06	2.33	**0.27**
0.864	2.00	2.38	**0.38**	1.86	2.34	**0.48**	1.99	2.33	**0.34**
1.08	1.81	2.38	**0.57**	1.74	2.34	**0.60**	1.90	2.33	**0.43**

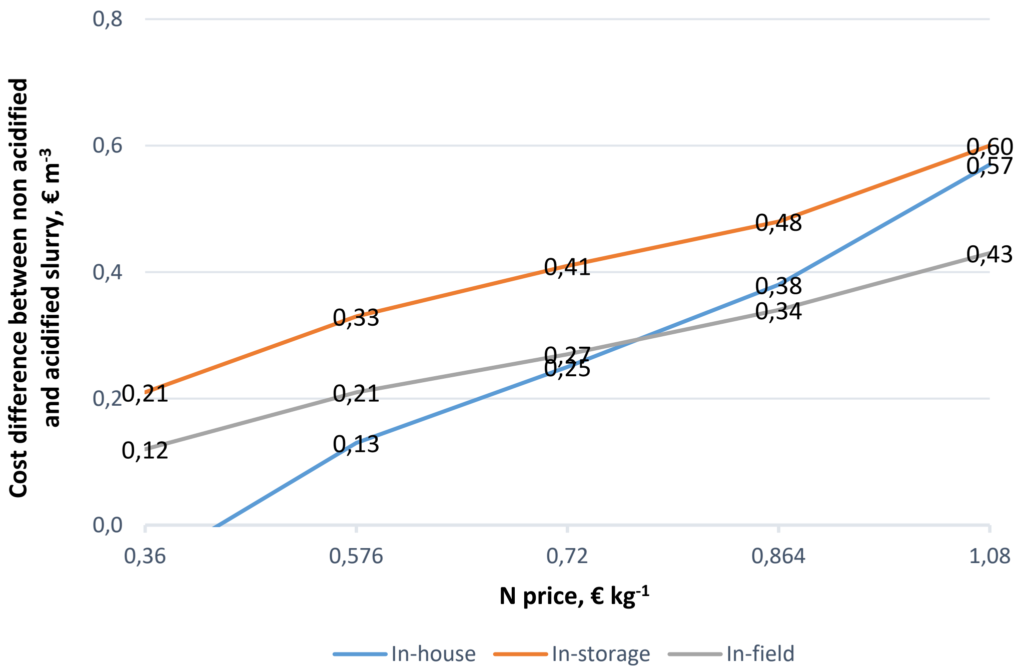

Figure 44. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

Table 64. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.36	1.91	2.52	**0.61**	1.88	2.35	**0.47**	2.04	2.34	**0.30**
0.576	1.45	2.52	**1.07**	1.74	2.35	**0.61**	1.92	2.34	**0.42**
0.72	1.14	2.52	**1.38**	1.64	2.35	**0.71**	1.84	2.34	**0.50**
0.864	0.84	2.52	**1.68**	1.55	2.35	**0.80**	1.77	2.34	**0.57**
1.08	0.38	2.52	**2.14**	1.40	2.35	**0.95**	1.65	2.34	**0.69**

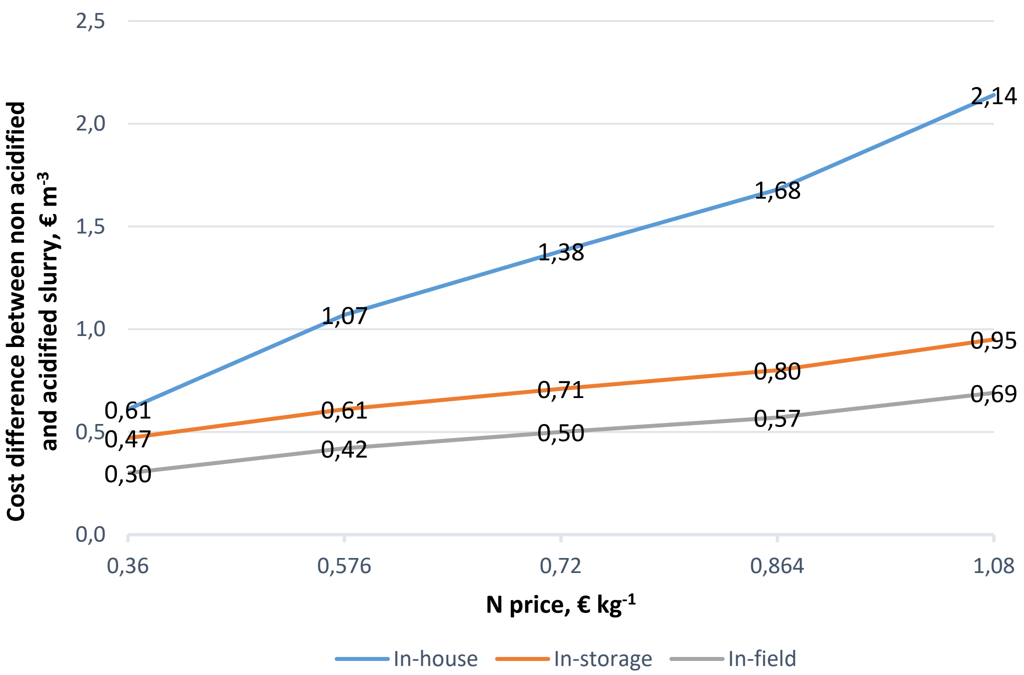

Figure 45. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

5.3.6. S price, Estonia

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

S price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.09 € m^{-3}.	↑0.10 € m^{-3}.
in-storage SAT:	↑0.09 € m^{-3}.	↑0.08 € m^{-3}.
in-field SAT:	↑0.08 € m^{-3}	↑0.09 € m^{-3}.

Table 65. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.11	2.22	2.38	**0.16**	2.03	2.34	**0.31**	2.15	2.33	**0.18**
0.176	2.16	2.38	**0.22**	1.97	2.34	**0.37**	2.09	2.33	**0.24**
0.22	2.13	2.38	**0.25**	1.93	2.34	**0.41**	2.06	2.33	**0.27**
0.264	2.09	2.38	**0.29**	1.90	2.34	**0.44**	2.02	2.33	**0.31**
0.33	2.03	2.38	**0.35**	1.84	2.34	**0.50**	1.97	2.33	**0.36**

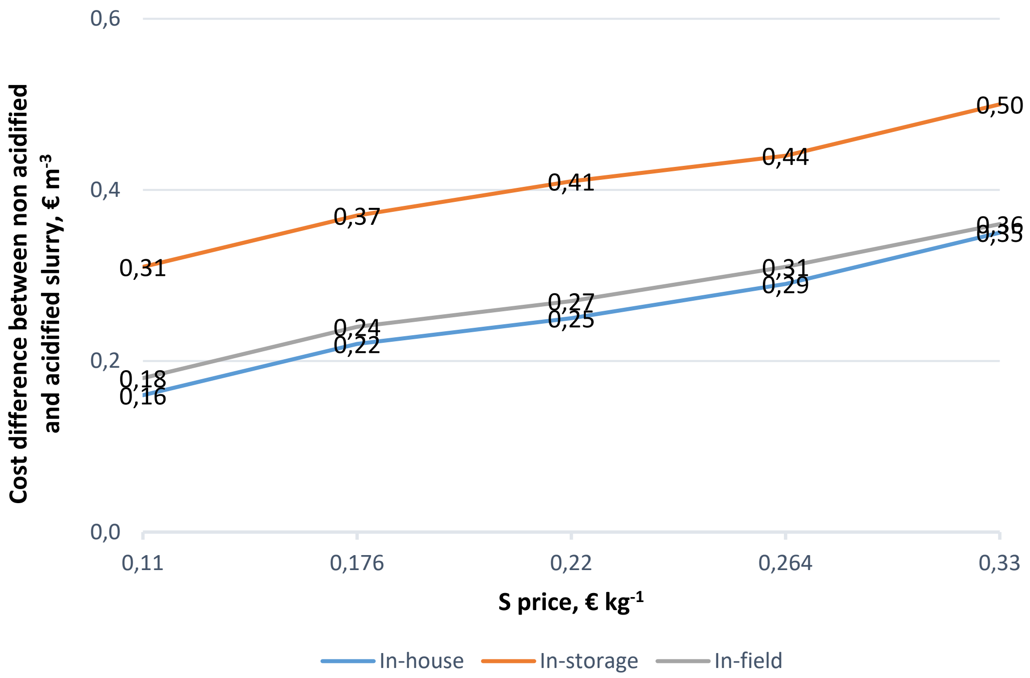

Figure 46. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

Table 66. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.11	1.26	2.52	**1.26**	1.73	2.35	**0.62**	1.94	2.34	**0.40**
0.176	1.19	2.52	**1.33**	1.68	2.35	**0.67**	1.88	2.34	**0.46**
0.22	1.14	2.52	**1.38**	1.64	2.35	**0.71**	1.84	2.34	**0.50**
0.264	1.10	2.52	**1.42**	1.60	2.35	**0.75**	1.81	2.34	**0.53**
0.33	1.03	2.52	**1.49**	1.55	2.35	**0.80**	1.75	2.34	**0.59**

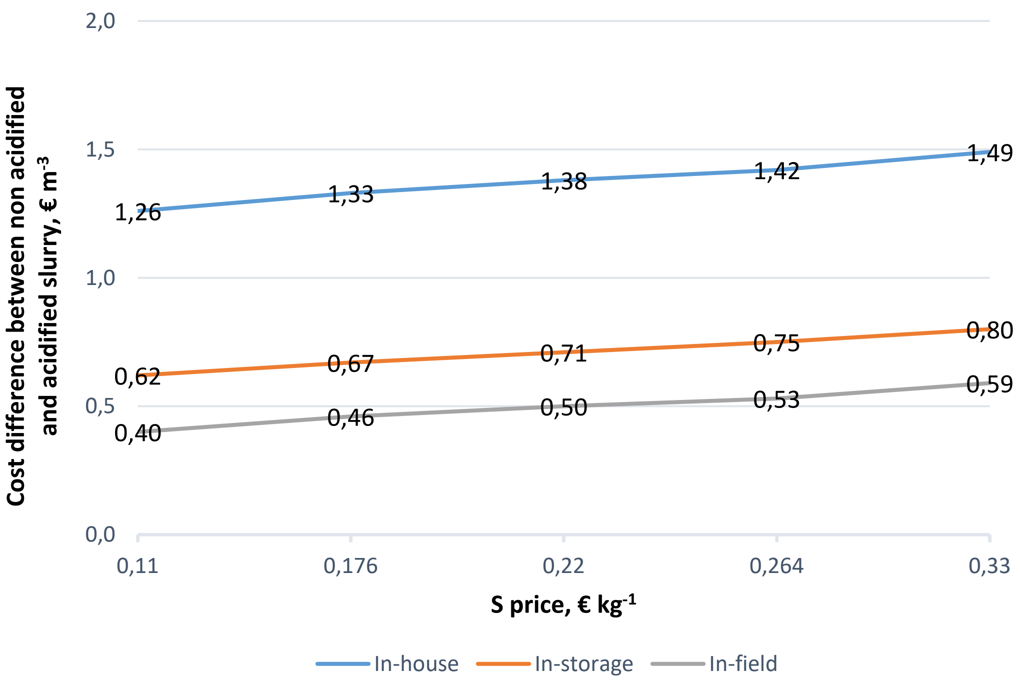

Figure 47. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

5.3.7. Summary, Estonia

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. All three SATs have cost- benefit by cattle and pig slurry both in Estonia. The minimal slurry amounts should be between 3,300–9,900 and 2,300–7,300 m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 54).

Acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save
2) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry
3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower)

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) decreases if acid amount per cubicmeter increases. While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The acid price by in-house SAT (127 € m^{-3}) is lower than by other SATs (150 € m^{-3}) and this is the reason why change of acid amount has smaller effect on cost-benefit by first SAT compared to others.

The calculations in paragraph 5.3 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts (Figure 50) show that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1} .

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount reaches the demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount per hectare and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 38 and 39 show also that the order of cover types is same for both, cattle and big slurries.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises (see 5.3.4).N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises (see 5.3.5). The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises (see 5.3.6).

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system. The analysis model will be available on project website.

5.4. Finland

5.4.1. Annual slurry amount, Finland

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The acid price in the calculations is 128 € t^{-1} for in-house acidification and 157 € t^{-1} for in-storage and in-field acidification. Minimum storage period 12 month. N-fertilisers is Urea (N46), 323 € t^{-1}. NS-fertiliser N21-S24, 245 € t^{-1}. Thus N price 0.7 € kg^{-1} and S price 0.41 € kg^{-1}. The prices of project partner countries are between 0.48–1 and 0.11–0.85 € kg^{-1} respectively.

All three SATs have cost- benefit by cattle and pig slurry both in Finland.

The minimal slurry amounts should be between 1,800–5,200 and 1,500–4,100 m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 67).

Table 67. The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit.

SAT	Dairy cows: Annual slurry amount, m^3	Dairy cows: Number of animal	Fatteners: Annual slurry amount, m^3	Fatteners: Number of animal per year
In-house	5,200	217	4,050	8,100
In-storage	1,752	73	1,455	2,910
In-field	4,800	200	4,050	8,100

Table 68. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1,200	10.81	6.96	**-3.85**	7.60	6.90	**-0.70**	11.60	6.88	**-4.72**
2,400	6.75	5.71	**-1.04**	5.26	5.66	**0.40**	7.17	5.64	**-1.53**
9,000	3.29	3.94	**0.65**	2.82	3.88	**1.06**	3.22	3.86	**0.64**
12,000	2.80	3.63	**0.83**	2.49	3.58	**1.09**	2.76	3.56	**0.80**
21,000	2.18	3.11	**0.93**	1.99	3.06	**1.07**	2.08	3.04	**0.96**
24,000	2.03	3.00	**0.97**	1.89	2.94	**1.05**	1.96	2.92	**0.96**
33,000	1.80	2.74	**0.94**	1.68	2.69	**1.01**	1.69	2.67	**0.98**
48,000	1.54	2.48	**0.94**	1.47	2.42	**0.95**	1.44	2.40	**0.96**

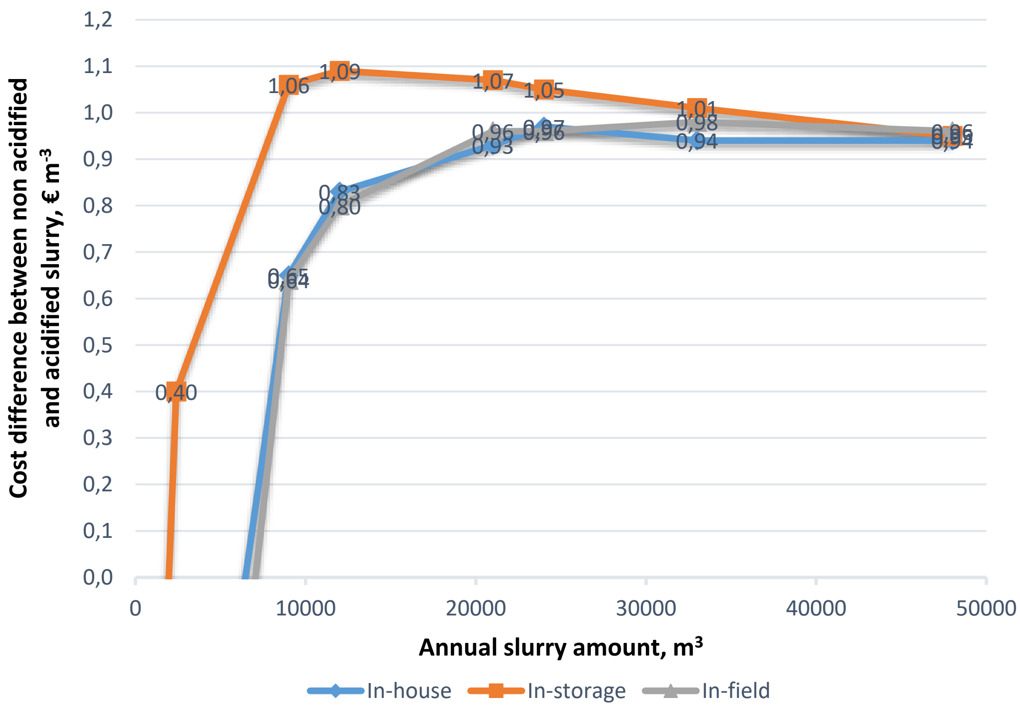

Figure 48. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

The biggest reason for economic benefit of SAT-s is the cost of slurry incorporation (55 € ha^{-1}) with disc harrow after spreading of non-acidified slurry. If slurry amount is 30 m^3 ha^{-1}, then incorporation cost is 1.67 € m^{-3}, which is saved if acidified slurry is applied to the field suface.

Table 69. Fattener slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
500	32.67	9.14	**-23.53**	12.37	8.89	**-3.48**	22.29	8.87	**-13.42**
2,500	7.88	5.85	**-2.03**	4.86	5.61	**0.75**	6.77	5.59	**-1.18**
5,000	4.25	4.85	**0.60**	3.38	4.60	**1.22**	4.30	4.58	**0.28**
9,000	2.58	4.14	**1.56**	2.53	3.90	**1.37**	3.01	3.88	**0.87**
21,000	1.12	3.32	**2.20**	1.70	3.07	**1.37**	1.88	3.05	**1.17**
33,000	0.64	2.95	**2.31**	1.39	2.71	**1.32**	1.49	2.68	**1.19**

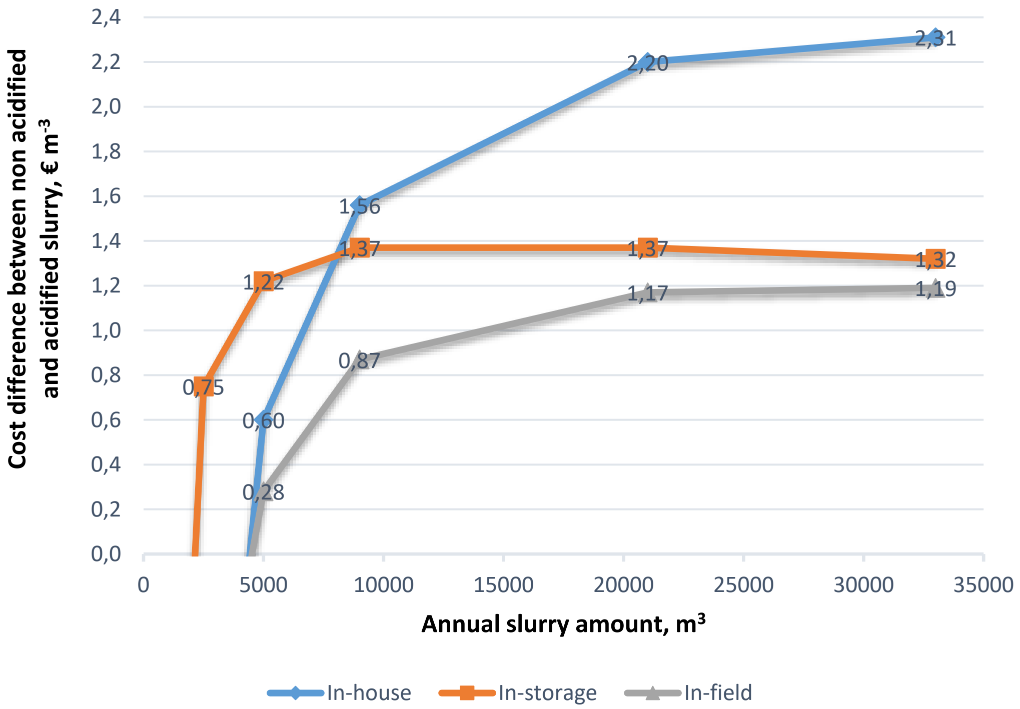

Figure 49. The cost decrease (€ m^{-3}) by use of fattener slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

5.4.2. Slurry amount per hectare, Finland

The calculations in paragraph 5.5.1 were done by slurry amount 30 m^3 ha^{-1}. Figure ….shows that cost benefit of slurry acidification with in-house SAT is drastically higher if slurry amount is 20 or 10 m^3 ha^{-1} and slurry is incorporated to soil by disc harrow after band spreading.

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of slurry (Table…). The table … shows also that the cost of slurry application rises if slurry amount decreases, but the rise is much smoother compared to cost of spreading+incorporation. The reason is that total number of turns on headland during year is smaller if hectare amount rises and total cost of turns is lower.

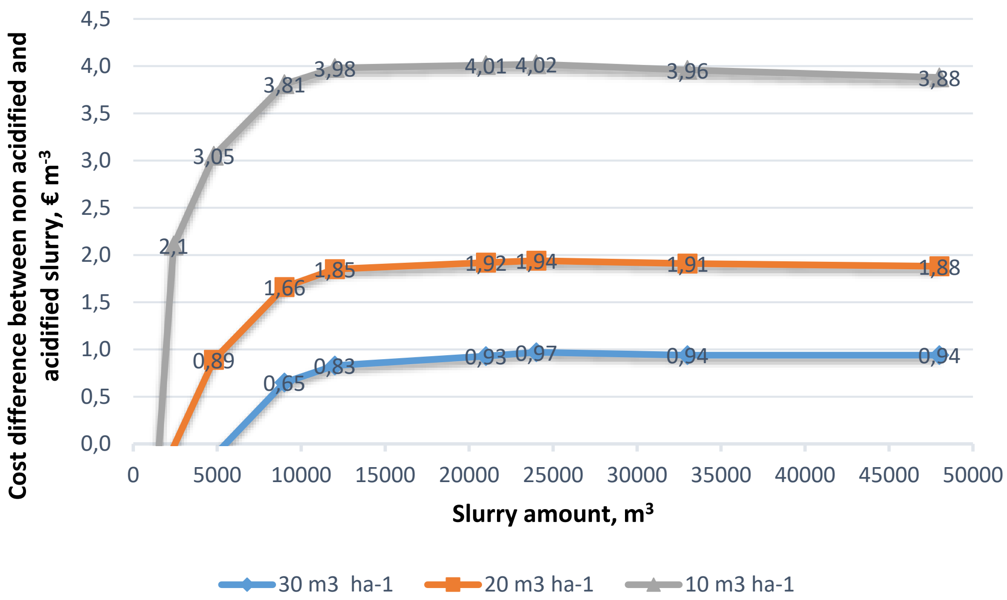

Figure 50.The difference of dairy cow slurry handling costs (€ m^{-3} of slurry) if slurry is acidified and not acidified, by different slurry amounts per hectare. Slurry is acidified with in-house SAT, not-acidified slurry is incorporated to soil by disc harrow after band spreading.

Table 70. The change of slurry spreading cost (€ m^{-3}) depending on slurry amount per hectare, if 12,000 m^3 of cattle slurry is spread annually.

Slurry spreading technology	Slurry amount, m^3 ha^{-1}		
	10	20	30
Band spreading, no incorporation	1.94	1.84	1.82
Band spreading, incorporation < 12 h	6.75	4.3	3,48

Another aspect, why low acidified slurry amount give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reductional effect is calculated until S amount is reached what is needed by crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases. In present example the cost reductions by 30, 20 or 10 m^3 ha^{-1} are 1.29, 0.65 and 0.43 € m^{-3} correspondingly.

The figure 51 below shows cost differences if not-acidfied slurry is not incorporated to the soil. The reason for cost change depending on hectare amounts of slurry is only different effect on cost reduction of mineral S.

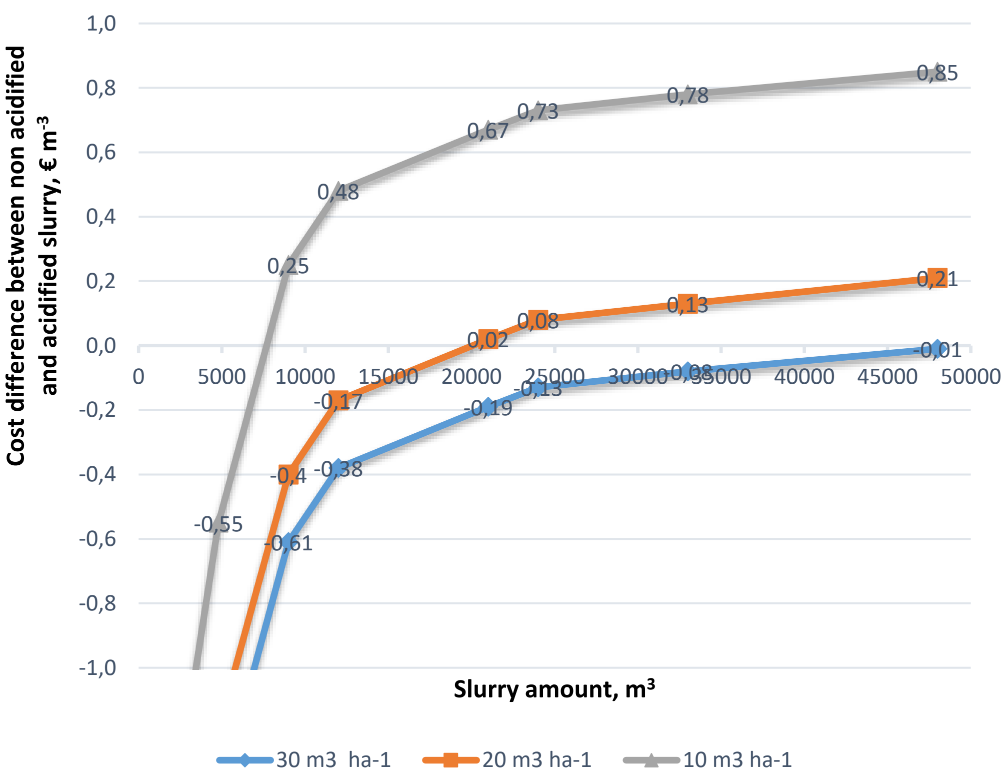

Figure 51. The difference of dairy cow slurry handling costs (€ m^{-3} of slurry) if slurry is acidified and not acidified, by different slurry amounts per hectare. Slurry is acidified with in-house SAT, not-acidified slurry is not incorporated.

5.4.3. Cover type, Finland

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 32 and 53 show also that the order of cover types is same for both, cattle and big slurries.

In Finland, the required minimum manure storage capacity is 12 months, if animal are housed inside all year around. For farms with grazing animals it is possible to decrease manure left on pasture from storage volume. In this case the minimum capacity is typically 8 months. Capacity can also be decreased if manure is given out from the farm, e.g. for processing. In this analysis is presumed that animal are housed in all year around and storage depth is 5 m. The capital cost of slurry storage cover calculated for these conditions are shown in the table 21.

Table 71. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3. The surface area of storage(s) is 4,200 m^2.

	In-house		
Cover type	Acid	No acid	**Dif.**
No cover	2.18	3.11	**0.93**
Chopped straw	2.37	3.23	**0.86**
Fibo clay balls (fraction 10-20 mm)	2.41	3.27	**0.86**
Floating foil	2.42	3.30	**0.88**
Hexa-cover plates	2.44	3.31	**0.87**
Peat	2.42	3.73	**1.31**
Rapeseed oil	2.41	4.58	**2.17**
Tent cover	2.45	3.85	**1.40**

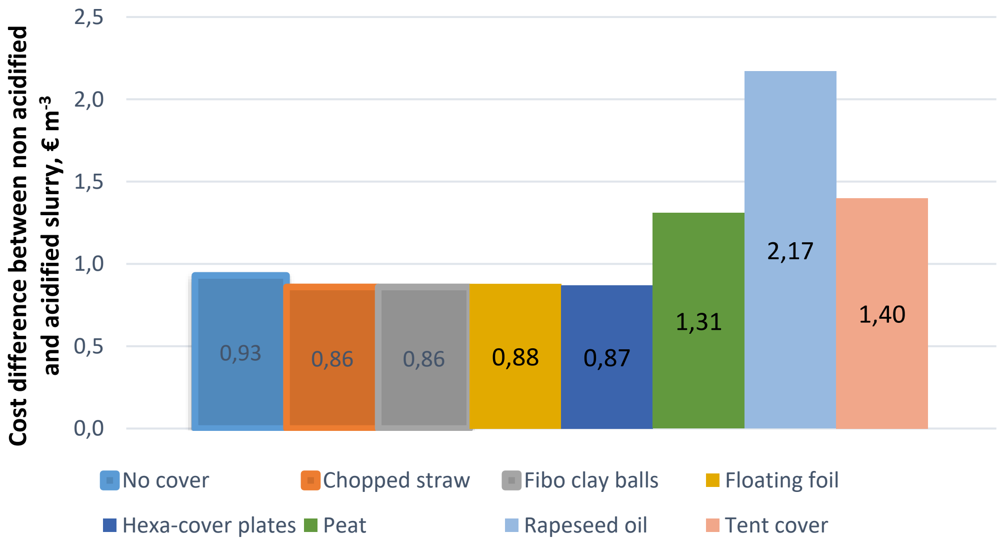

Figure 52. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Table 72. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	Acid	In-house No acid	Dif.
No cover	1.12	3.32	**2.20**
Chopped straw	1.36	3.42	**2.06**
Fibo clay balls (fraction 10-20 mm)	1.41	3.47	**2.06**
Floating foil	1.43	3.49	**2.06**
Hexa-cover plates	1.45	3.51	**2.06**
Peat	1.43	3.93	**2.50**
Rapeseed oil	1.41	4.77	**3.36**
Tent cover	1.47	4.04	**2.57**

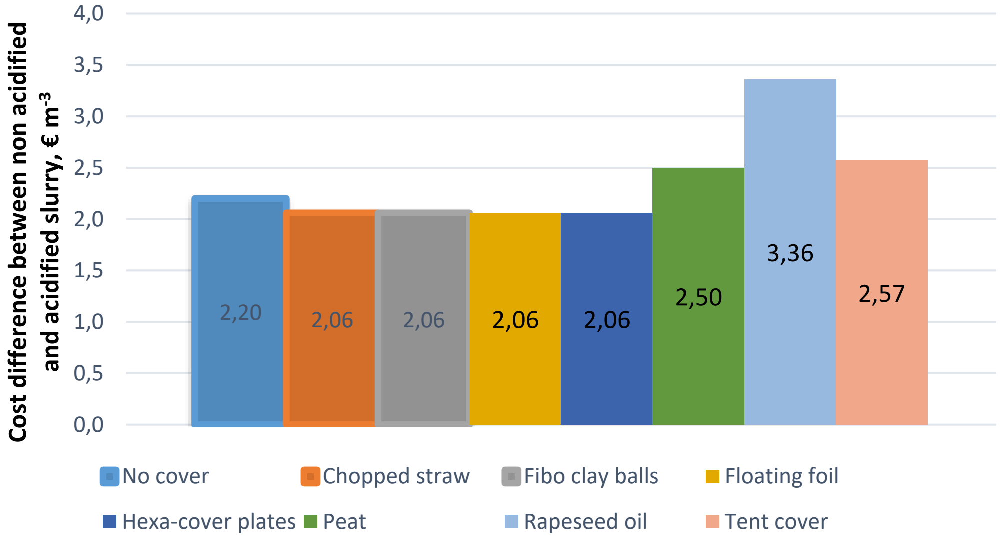

Figure 53. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners.

5.4.4. Acid consumption, Finland

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) decreases if acid amount per cubicmeter increases.

If acid consumption ↑ 1 l m^{-3}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↓0.29 € m^{-3}	↓0.27 € m^{-3}
in-storage SAT:	↓0.35 € m^{-3}	↓0.35 € m^{-3}
in-field SAT:	↓0.36 € m^{-3}	↓0.36 € m^{-3}

Acid content change in slurry has lowest impact by in-house SAT and biggest by in-field SAT. The reason is that the acid price for in-house SAT is lower (128 € t^{-1}) than by other SATs (157 € t^{-1}).

Table 73. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	1.22	3.11	**1.89**	1.15	3.06	**1.91**	1.45	3.04	**1.59**
3	1.72	3.11	**1.39**	1.77	3.06	**1.29**	2.08	3.04	**0.96**
4	2.03	3.11	**1.08**	2.14	3.06	**0.92**	2.46	3.04	**0.58**
5	2.34	3.11	**0.77**	2.51	3.06	**0.55**	2.84	3.04	**0.20**
7	2.96	3.11	**0.15**	3.25	3.06	**-0.19**	3.61	3.04	**-0.57**

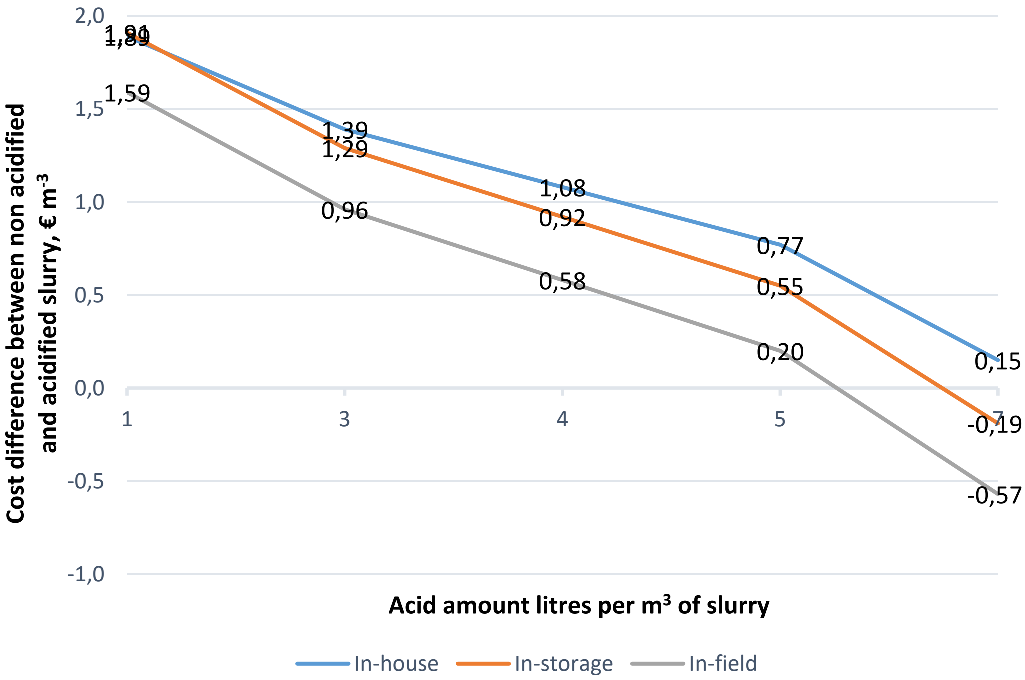

Figure 54. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

Table 74. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	0.58	3.32	**2.74**	1.09	3.07	**1.98**	1.39	3.05	**1.66**
3	0.97	3.32	**2.35**	1.70	3.07	**1.37**	2.03	3.05	**1.02**
4	1.28	3.32	**2.04**	2.07	3.07	**1.00**	2.41	3.05	**0.64**
5	1.59	3.32	**1.73**	2.44	3.07	**0.63**	2.79	3.05	**0.26**
7	2.21	3.32	**1.11**	3.18	3.07	**-0.11**	3.55	3.05	**-0.50**

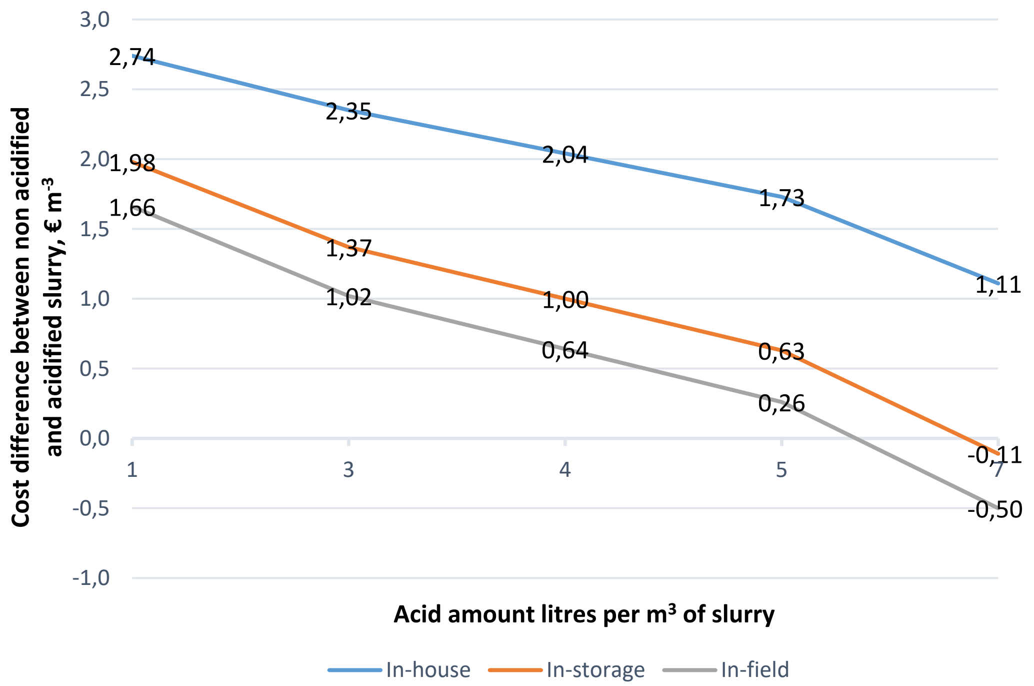

Figure 55. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

5.4.5. N_{tot} in slurry, Finland

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

If N_{tot} content in slurry ↑ 1 kg m^{-3} , then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.14 € m^{-3}.	↑0.29 € m^{-3}.
in-storage SAT:	↑0.11 € m^{-3}.	↑0.11 € m^{-3}.
in-field SAT:	↑0.10 € m^{-3}	↑0.09 € m^{-3}.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.

Table 75. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content	In-house			In-storage			In-field		
kg m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
3				2.15	3.02	**0.87**	2.21	3.01	**0.80**
4	2.40	3.06	**0.66**	2.06	3.04	**0.98**	2.14	3.02	**0.88**
5	2.28	3.09	**0.81**	1.97	3.06	**1.09**	2.06	3.04	**0.98**
6	2.17	3.11	**0.94**	1.88	3.08	**1.20**	1.99	3.06	**1.07**
7	2.06	3.14	**1.08**						

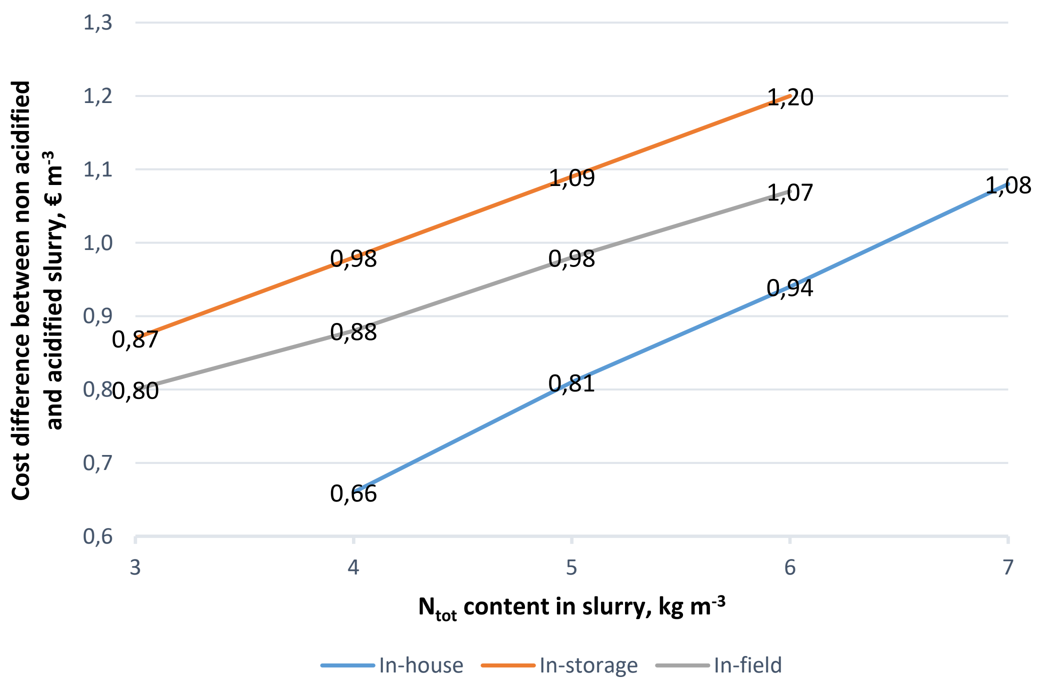

Figure 56. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Table 76. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
4				1.83	3.04	**1.21**	1.98	3.02	**1.04**
5	1.58	3.21	**1.63**	1.74	3.06	**1.32**	1.91	3.04	**1.13**
6	1.35	3.27	**1.92**	1.65	3.08	**1.43**	1.84	3.06	**1.22**
7	1.12	3.32	**2.20**	1.56	3.10	**1.54**	1.77	3.07	**1.30**
8	0.89	3.37	**2.48**						

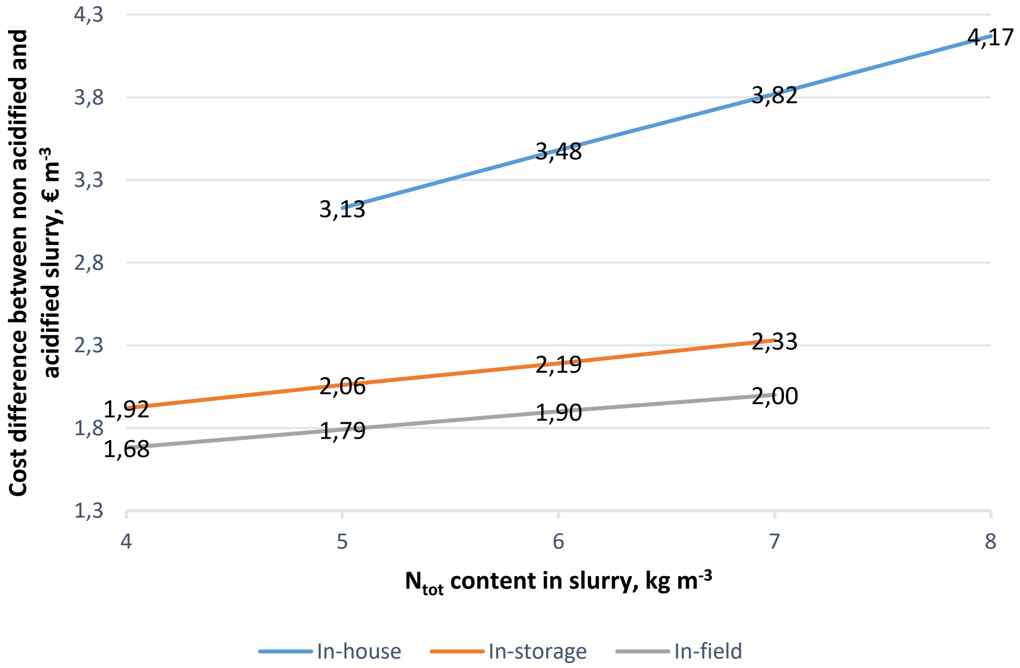

Figure 57. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

5.4.6. N price, Finland

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

N price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.089 € m^{-3}.	↑0.21 € m^{-3}.
in-storage SAT:	↑0.057 € m^{-3}.	↑0.07 € m^{-3}.
in-field SAT:	↑0.046 € m^{-3}	↑0.05 € m^{-3}.

The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.
Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

Table 77. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.35	2.49	3.11	**0.62**	2.19	3.06	**0.87**	2.24	3.04	**0.80**
0.56	2.30	3.11	**0.81**	2.07	3.06	**0.99**	2.14	3.04	**0.90**
0.7	2.18	3.11	**0.93**	1.99	3.06	**1.07**	2.08	3.04	**0.96**
0.84	2.06	3.11	**1.05**	1.91	3.06	**1.15**	2.02	3.04	**1.02**
1.05	1.87	3.11	**1.24**	1.79	3.06	**1.27**	1.92	3.04	**1.12**

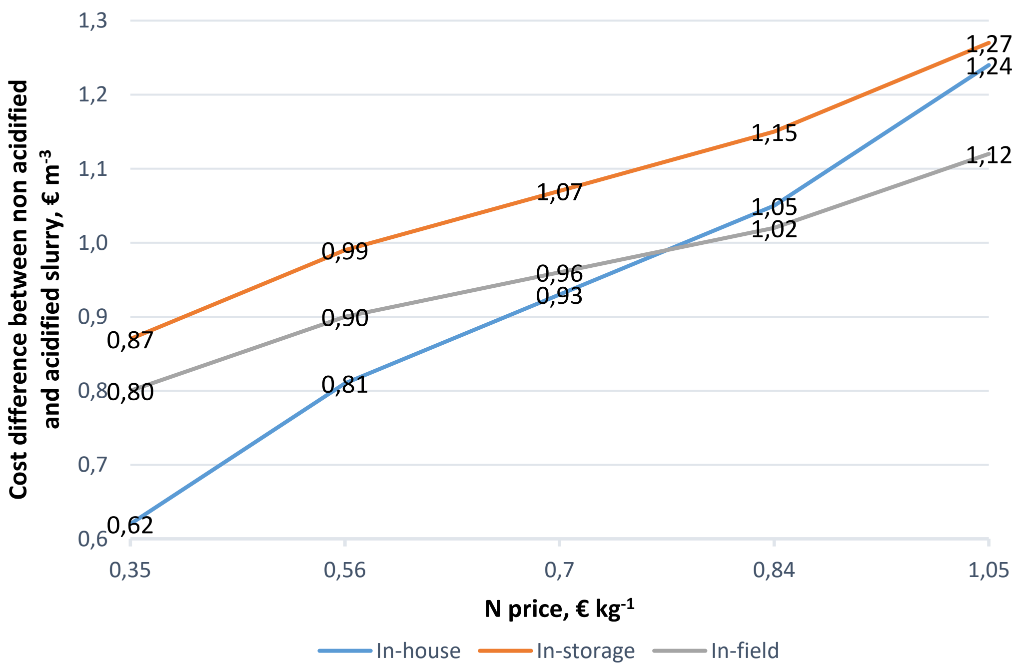

Figure 58. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

Table 78. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.35	1.87	3.32	**1.45**	1.93	3.07	**1.14**	2.07	3.05	**0.98**
0.56	1.42	3.32	**1.90**	1.79	3.07	**1.28**	1.96	3.05	**1.09**
0.7	1.12	3.32	**2.20**	1.70	3.07	**1.37**	1.88	3.05	**1.17**
0.84	0.83	3.32	**2.49**	1.61	3.07	**1.46**	1.81	3.05	**1.24**
1.05	0.38	3.32	**2.94**	1.47	3.07	**1.60**	1.70	3.05	**1.35**

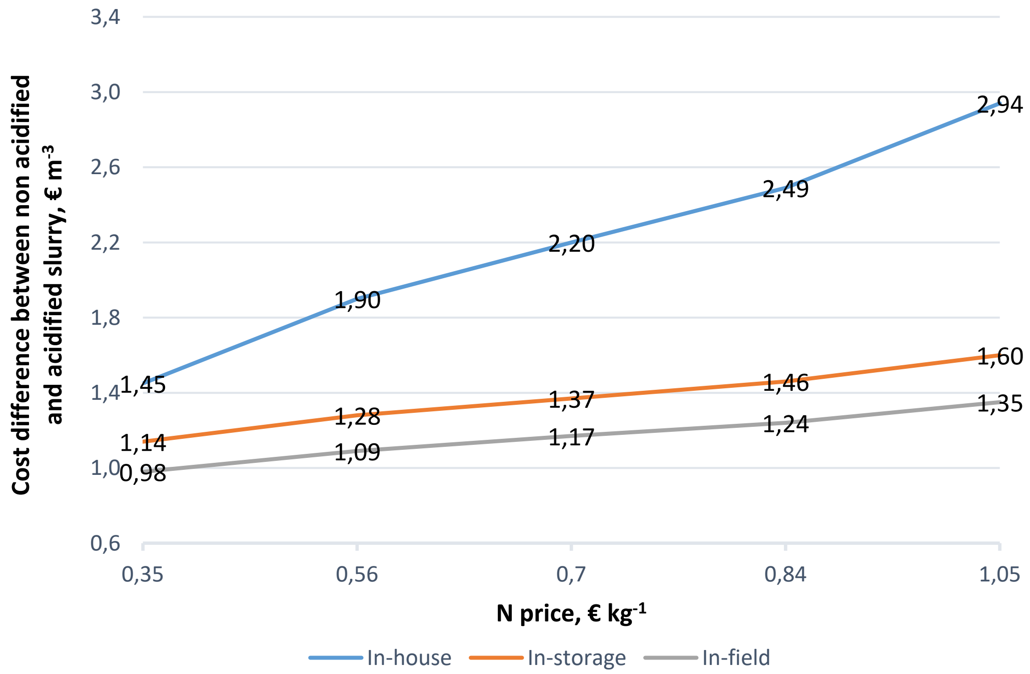

Figure 59. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

5.4.7. S price, Finland

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

S price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.08 € m^{-3}.	↑0.10 € m^{-3}.
in-storage SAT:	↑0.08 € m^{-3}.	↑0.08 € m^{-3}.
in-field SAT:	↑0.08 € m^{-3}	↑0.09 € m^{-3}.

Table 79. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.205	2.35	3.11	**0.76**	2.16	3.06	**0.90**	2.25	3.04	**0.79**
0.328	2.25	3.11	**0.86**	2.06	3.06	**1.00**	2.15	3.04	**0.89**
0.4	2.19	3.11	**0.92**	2.00	3.06	**1.06**	2.09	3.04	**0.95**
0.492	2.11	3.11	**1.00**	1.92	3.06	**1.14**	2.01	3.04	**1.03**
0.615	2.01	3.11	**1.10**	1.82	3.06	**1.24**	1.91	3.04	**1.13**

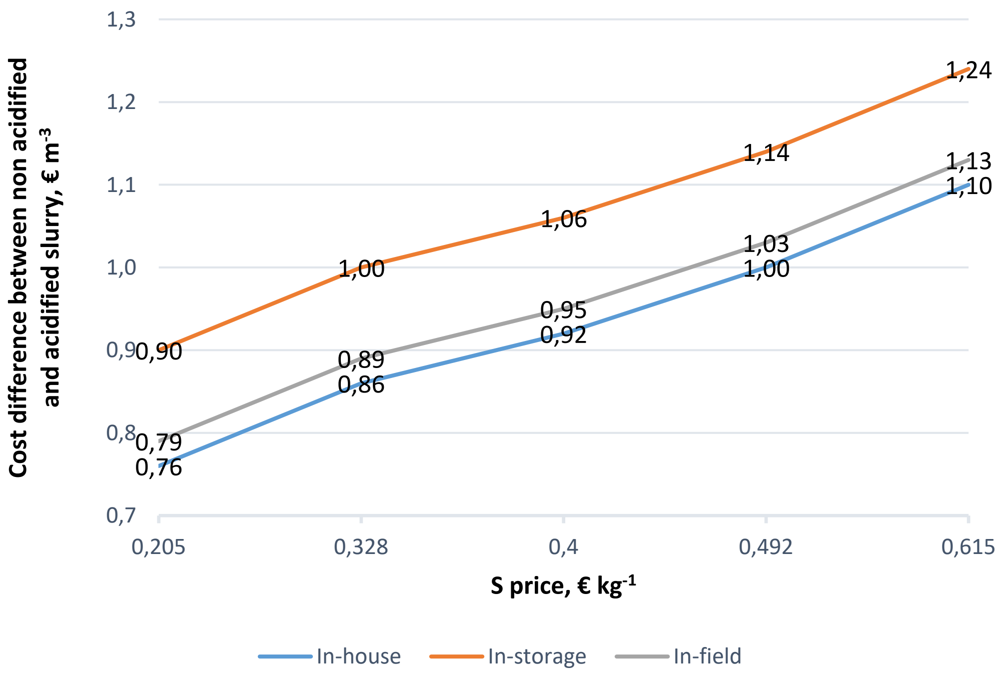

Figure 60. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

Table 80. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.205	1.34	3.32	**1.98**	1.87	3.07	**1.20**	2.05	3.05	**1.00**
0.328	1.21	3.32	**2.11**	1.77	3.07	**1.30**	1.94	3.05	**1.11**
0.4	1.13	3.32	**2.19**	1.71	3.07	**1.36**	1.88	3.05	**1.17**
0.492	1.04	3.32	**2.28**	1.63	3.07	**1.44**	1.81	3.05	**1.24**
0.615	0.91	3.32	**2.41**	1.53	3.07	**1.54**	1.70	3.05	**1.35**

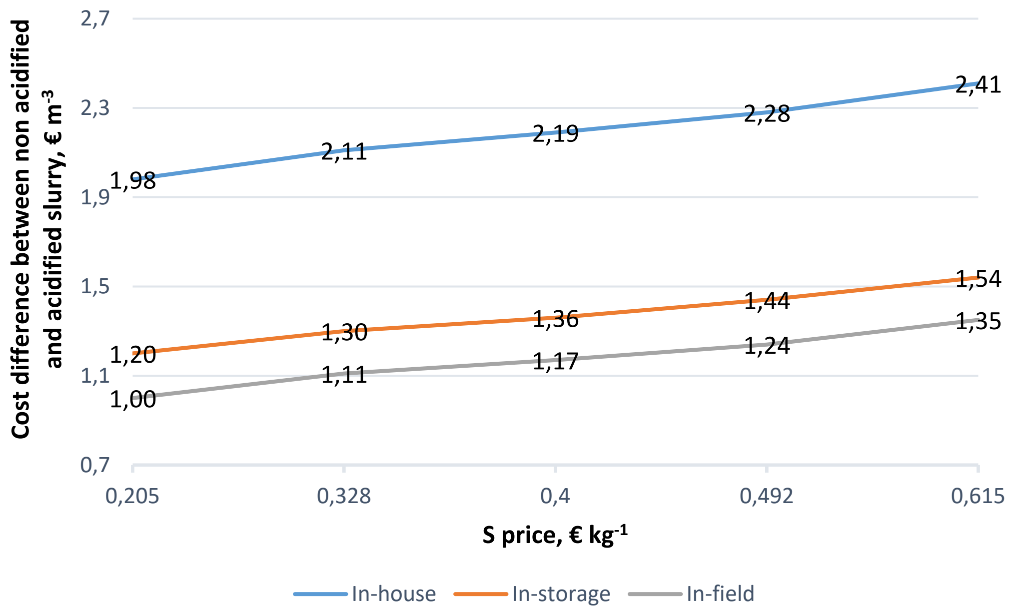

Figure 61. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

5.4.8. Summary, Finland

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. All three SATs have cost- benefit by cattle and pig slurry both in Finland.

The minimal slurry amounts should be between 1,800–5,200 and 1,500–4,100 m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 67).

Acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save
2) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry

3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower)

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) decreases if acid amount per cubicmeter increases. While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The acid price by in-house SAT (128 € m^{-3}) is lower than by other SATs (157 € m^{-3}) and this is the reason why change of acid amount has smaller effect on cost-benefit by first SAT compared to others.

The biggest reason for economic benefit of SAT-s is the cost of slurry incorporation (32 € ha^{-1}) with disc harrow after spreading of non-acidified slurry. If slurry amount is 30 m^3 ha^{-1}, then incorporation cost is 1.67 € m^{-3}, which is saved if acidified slurry is applied to the field suface.

The calculations in paragraph 5.4 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts (Figure 50) show that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1} .

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount reaches the demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount per hectare and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 52 and 53 show also that the order of cover types is same for both, cattle and big slurries.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises (see 5.4.5). N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry.

The reason is that by in-house acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises (see 5.4.6). The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises (see 5.4.7).

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system. The analysis model will be available on project website.

5.5. Germany

5.5.1. Annual slurry amount, Germany

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry.

The acid price in the calculations is 128 € t^{-1} for in-house acidification and 157 € t^{-1} for in-storage and in-field acidification. Minimum storage period 6 month. N-fertilisers is CAN 27, 213 € t^{-1}. NS-fertiliser ASS 27/13, 236 € t^{-1}. Thus N price 0.79 € kg^{-1} and S price 0.18 € kg^{-1}. The prices of project partner countries are between 0.48–1 and 0.11–0.85€ kg^{-1} respectively.

All three SATs have cost- benefit by cattle and pig slurry both in Germany.

The minimal slurry amounts should be between 3,100–13,100 and 2,200–9,700 m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 81).

Table 81. The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit.

SAT	Dairy cows		Fatteners	
	Annual slurry amount, m^3	Number of animal	Annual slurry amount, m^3	Number of animal per year
In-house	9,024	376	4,817	9,634
In-storage	3,096	129	2,175	4,349
In-field	13,056	544	9,667	19,334

Table 82. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1,200	11.75	6.76	**-4.99**	7.98	6.69	**-1.29**	14.50	6.66	**-7.84**

2,400	7.44	5.52	**-1.92**	5.68	5.45	**-0.23**	8.88	5.42	**-3.46**
9,000	3.78	3.78	**0.00**	3.24	3.71	**0.47**	4.00	3.68	**-0.32**
12,000	3.25	3.48	**0.23**	2.91	3.41	**0.50**	3.44	3.38	**-0.06**
21,000	2.59	2.97	**0.38**	2.39	2.90	**0.51**	2.64	2.87	**0.23**
24,000	2.43	2.87	**0.44**	2.28	2.79	**0.51**	2.48	2.77	**0.29**
33,000	2.17	2.62	**0.45**	2.06	2.55	**0.49**	2.17	2.52	**0.35**
48,000	1.89	2.36	**0.47**	1.84	2.29	**0.45**	1.88	2.26	**0.38**

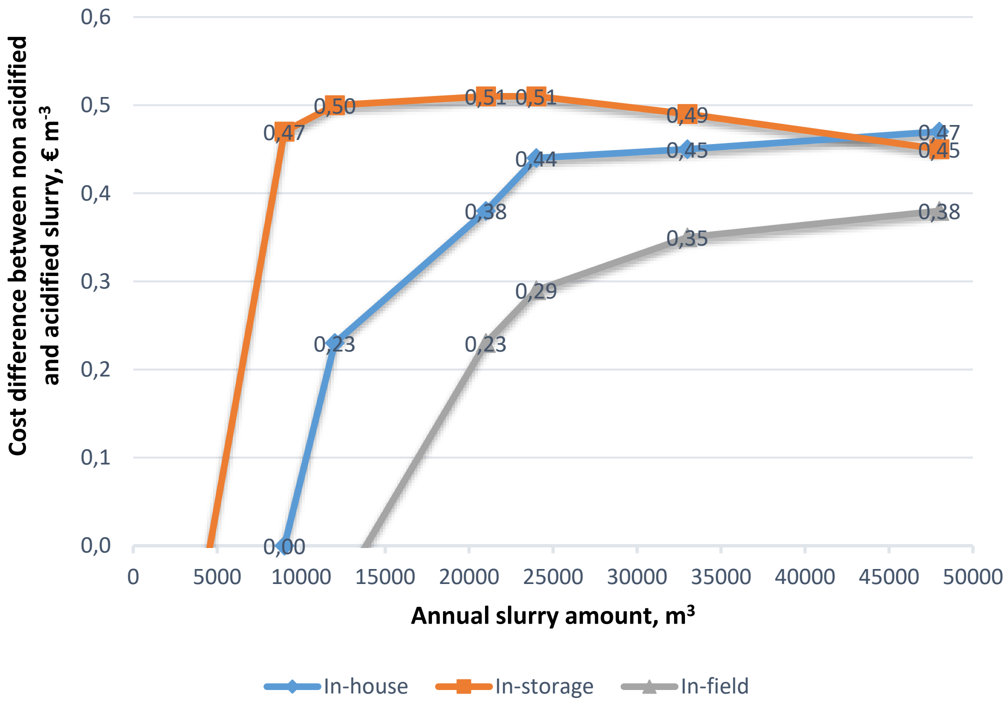

Figure 62. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Table 83. Fattener slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
500	34.29	9.02	**-25.27**	12.55	8.68	**-3.87**	28.51	8.65	**-19.86**
2,500	8.44	5.75	**-2.69**	5.26	5.41	**0.15**	8.41	5.38	**-3.03**
5,000	4.65	4.76	**0.11**	3.79	4.42	**0.63**	5.34	4.39	**-0.95**
9,000	2.90	4.07	**1.17**	2.92	3.73	**0.81**	3.77	3.70	**-0.07**
21,000	1.36	3.26	**1.90**	2.07	2.92	**0.85**	2.41	2.89	**0.48**
33,000	0.84	2.91	**2.07**	1.74	2.57	**0.83**	1.94	2.54	**0.60**

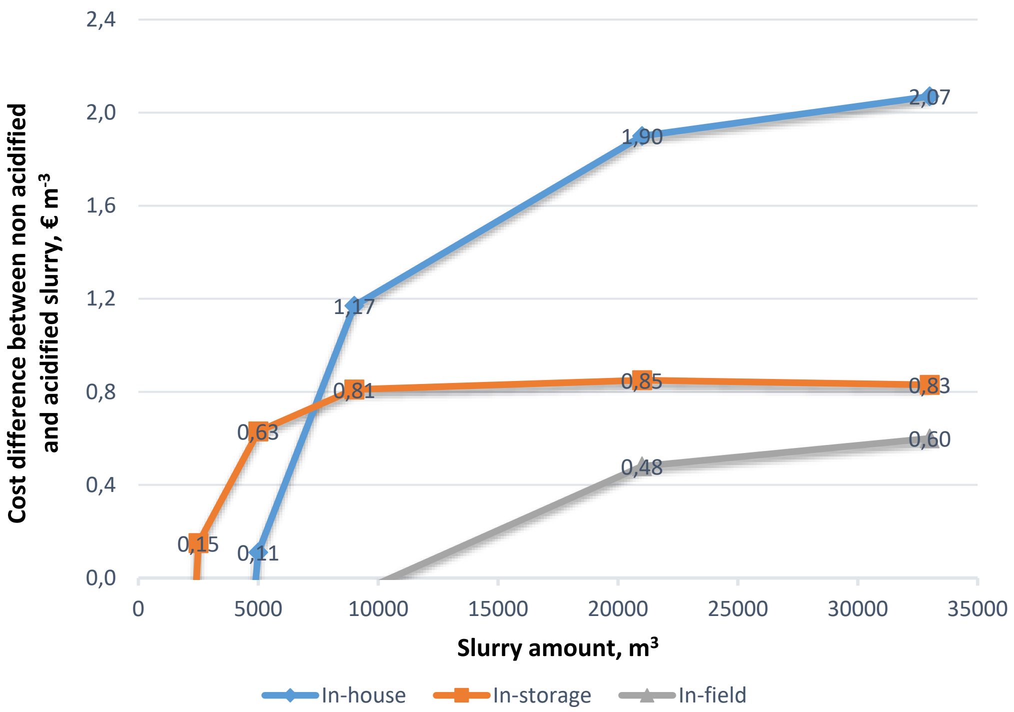

Figure 63. The cost decrease (€ m^{-3}) by use of fattener slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

5.5.2. Cover type, Germany

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 64 and 65 show also that the order of cover types is same for both, cattle and big slurries.

In Germany, the required minimum manure storage capacity is 6 months. In this analysis is presumed that animal are housed in all year around and storage depth is 5 m. The capital cost of slurry storage cover calculated for these conditions are shown in the table 21.

Table 84. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different

type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	Acid	In-house No acid	**Dif.**
No cover	2.59	2.97	**0.38**
Chopped straw	2.81	3.00	**0.19**
Fibo clay balls (fraction 10-20 mm)	2.87	3.01	**0.14**
Floating foil	2.88	3.02	**0.14**
Hexa-cover plates	2.90	3.03	**0.13**
Peat	2.88	3.24	**0.36**
Rapeseed oil	2.87	3.66	**0.79**
Tent cover	2.92	3.29	**0.37**

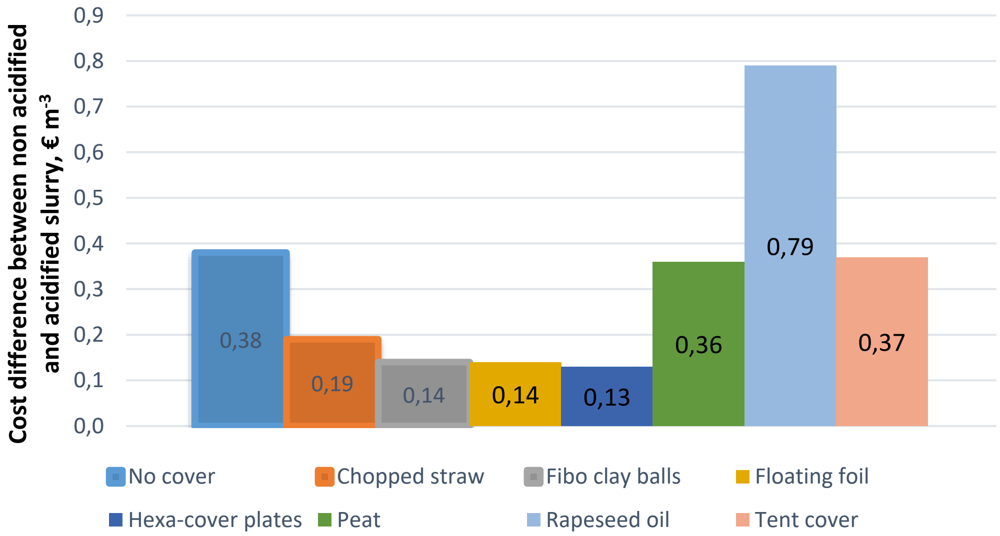

Figure 64. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Table 85. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	Acid	In-house No acid	**Dif.**
No cover	1.36	3.26	**1.90**
Chopped straw	1.64	3.27	**1.63**
Fibo clay balls (fraction 10-20 mm)	1.71	3.28	**1.57**
Floating foil	1.73	3.29	**1.56**

Hexa-cover plates	1.75	3.29	**1.54**
Peat	1.73	3.51	**1.78**
Rapeseed oil	1.71	3.93	**2.22**
Tent cover	1.77	3.56	**1.79**

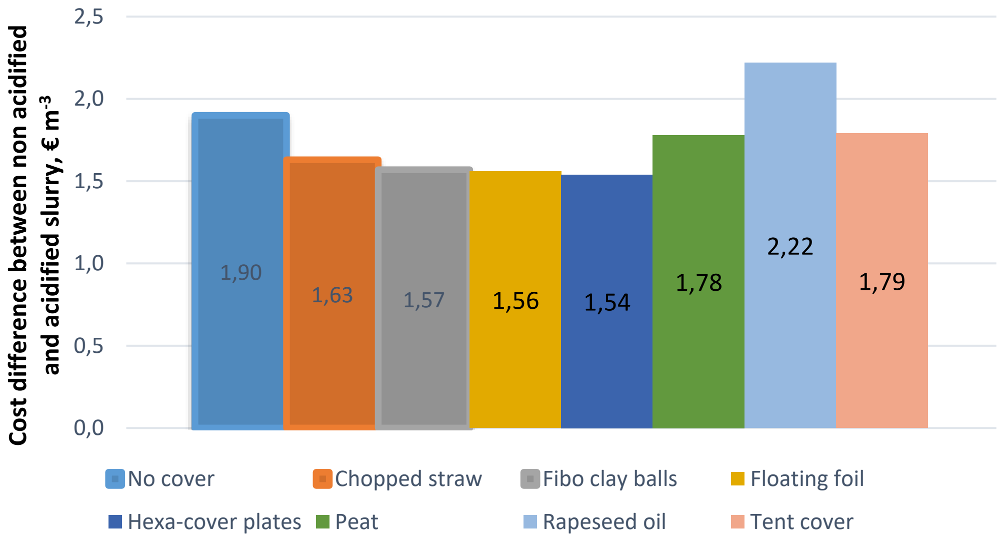

Figure 65. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners.

5.5.3. Acid consumption, Germany

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) decreases if acid amount per cubicmeter increases.

If acid consumption ↑ 1 l m^{-3}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↓0.32 € m^{-3}	↓0.31 € m^{-3}
in-storage SAT:	↓0.38 € m^{-3}	↓0.38 € m^{-3}
in-field SAT:	↓0.39 € m^{-3}	↓0.39 € m^{-3}

Acid content change in slurry has lowest impact by in-house SAT and biggest by in-field SAT. The reason is that the acid price for in-house SAT is lower (128 € t^{-1}) than by other SATs (157 € t^{-1}).

Table 86. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	1.50	2.97	**1.47**	1.43	2.90	**1.47**	1.90	2.87	**0.97**
3	2.09	2.97	**0.88**	2.15	2.90	**0.75**	2.64	2.87	**0.23**
4	2.42	2.97	**0.55**	2.54	2.90	**0.36**	3.04	2.87	**-0.17**
5	2.75	2.97	**0.22**	2.94	2.90	**-0.04**	3.44	2.87	**-0.57**
7	3.42	2.97	**-0.45**	3.73	2.90	**-0.83**	4.25	2.87	**-1.38**

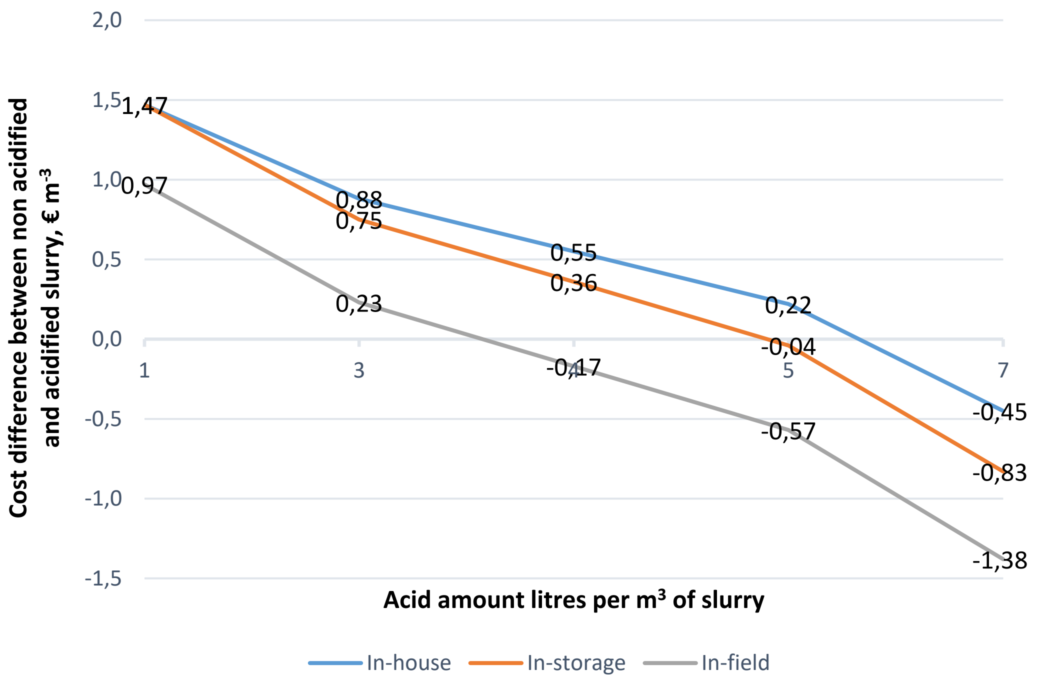

Figure 66. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

Table 87. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	0,66	3.26	**2.60**	1.35	2.92	**1.57**	1.84	2.89	**1.05**
3	1,19	3.26	**2.07**	2.07	2.92	**0.85**	2.57	2.89	**0.32**
4	1,52	3.26	**1.74**	2.46	2.92	**0.46**	2.97	2.89	**-0.08**
5	1,86	3.26	**1.40**	2.86	2.92	**0.06**	3.38	2.89	**-0.49**
7	2,52	3.26	**0.74**	3.65	2.92	**-0.73**	4.19	2.89	**-1.30**

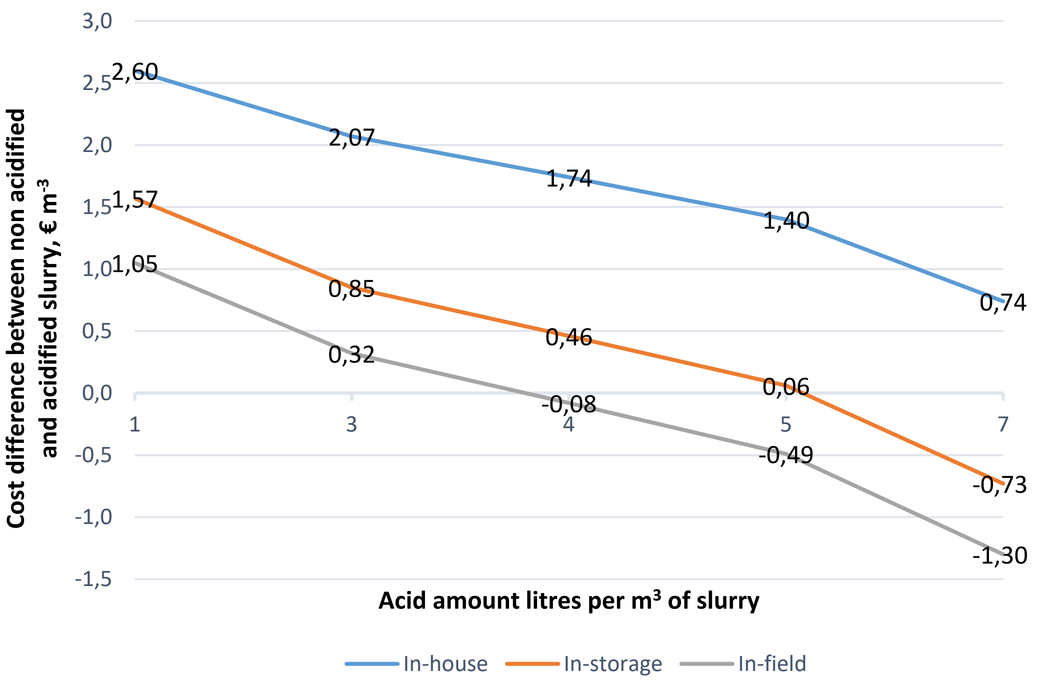

Figure 67. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

5.5.4. N_{tot} in slurry, Germany

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

If N_{tot} content in slurry ↑ 1 kg m^{-3} , then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.18 € m^{-3}.	↑0.35 € m^{-3}.
in-storage SAT:	↑0.14 € m^{-3}.	↑0.14 € m^{-3}.
in-field SAT:	↑0.11 € m^{-3}	↑0.11 € m^{-3}.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.

Table 88. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content	In-house			In-storage			In-field		
kg m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
3				2.58	2.85	**0.27**	2.79	2.84	**0.05**
4	2.85	2.91	**0.06**	2.47	2.88	**0.41**	2.70	2.86	**0.16**

5	2.71	2.94	**0.23**	2.36	2.91	**0.55**	2.61	2.88	**0.27**
6	2.57	2.98	**0.41**	2.25	2.94	**0.69**	2.53	2.90	**0.37**
7	2.44	3.01	**0.57**						

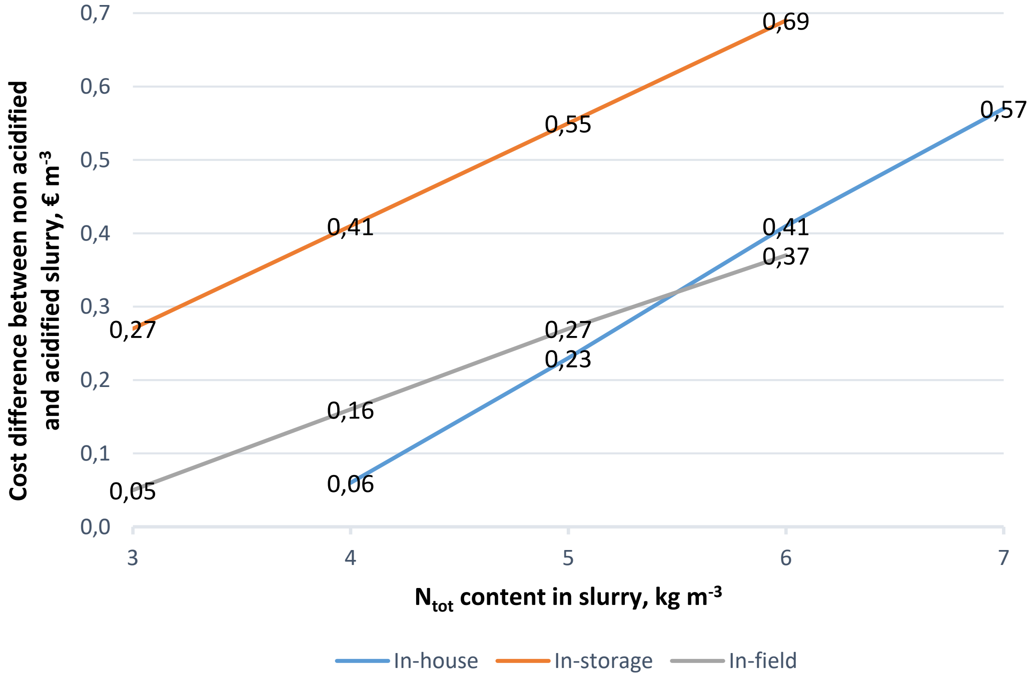

Figure 68. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N$_{tot}$ content in slurry

Table 89. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N$_{tot}$ content in slurry

Ntot content kg m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
4				2.23	2.88	**0.65**	2.54	2.86	**0.32**
5	1.91	3.12	**1.21**	2.12	2.91	**0.79**	2.45	2.88	**0.43**
6	1.63	3.19	**1.56**	2.01	2.94	**0.93**	2.36	2.90	**0.54**
7	1.36	3.26	**1.90**	1.90	2.96	**1.06**	2.28	2.92	**0.64**
8	1.08	3.33	**2.25**						

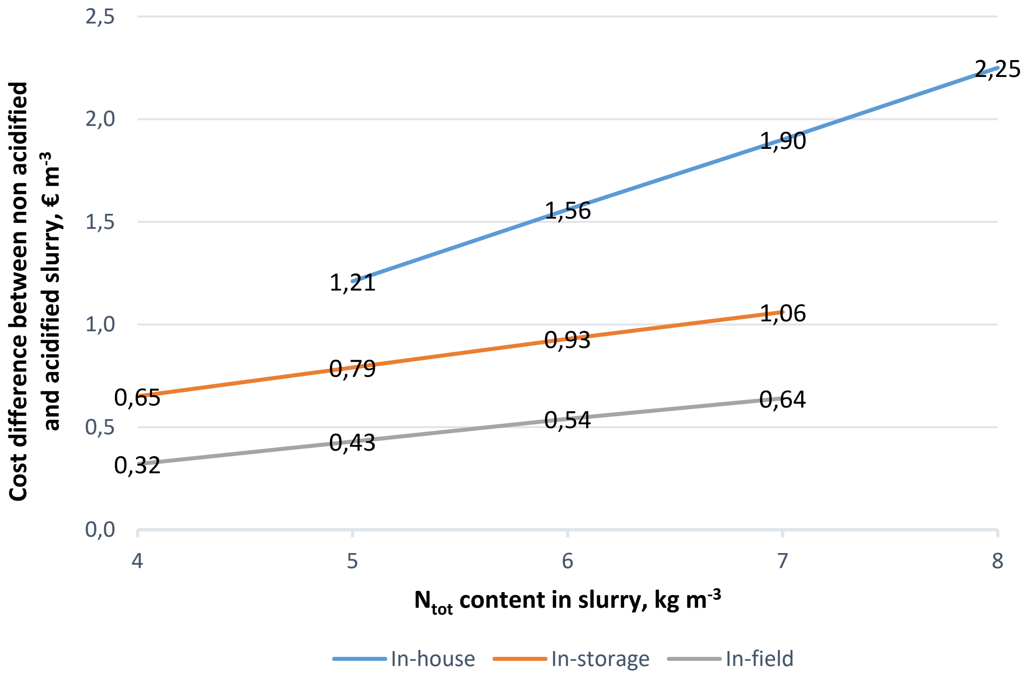

Figure 69. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

5.5.5. N price, Germany

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises.

N price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.089 € m^{-3}.	↑0.21 € m^{-3}.
in-storage SAT:	↑0.057 € m^{-3}.	↑0.07 € m^{-3}.
in-field SAT:	↑0.046 € m^{-3}	↑0.05 € m^{-3}.

The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.
Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

Table 90. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.395	2.93	2.97	**0.04**	2.61	2.90	**0.29**	2.81	2.87	**0.06**

0.632	2.72	2.97	**0.25**	2.47	2.90	**0.43**	2.71	2.87	**0.16**
0.79	2.58	2.97	**0.39**	2.38	2.90	**0.52**	2.63	2.87	**0.24**
0.948	2.44	2.97	**0.53**	2.29	2.90	**0.61**	2.56	2.87	**0.31**
1.185	2.23	2.97	**0.74**	2.16	2.90	**0.74**	2.45	2.87	**0.42**

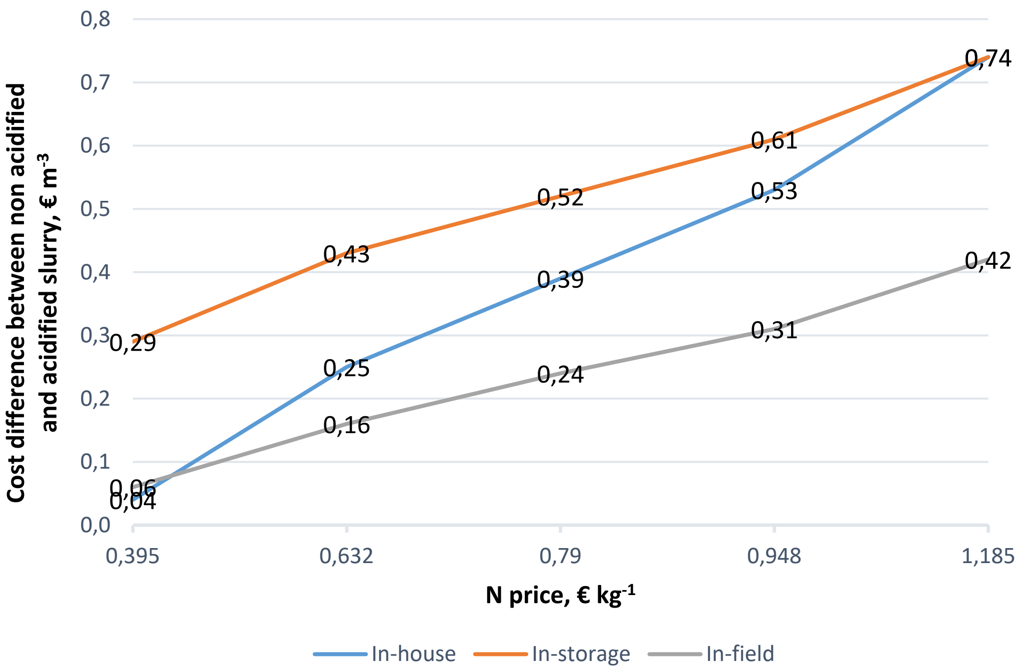

Figure 70. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

Table 91. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.395	2.19	3.26	**1.07**	2.32	2.92	**0.60**	2.61	2.89	**0.28**
0.632	1.69	3.26	**1.57**	2.17	2.92	**0.75**	2.49	2.89	**0.40**
0.79	1.35	3.26	**1.91**	2.06	2.92	**0.86**	2.40	2.89	**0.49**
0.948	1.02	3.26	**2.24**	1.96	2.92	**0.96**	2.32	2.89	**0.57**
1.185	0.51	3.26	**2.75**	1.80	2.92	**1.12**	2.20	2.89	**0.69**

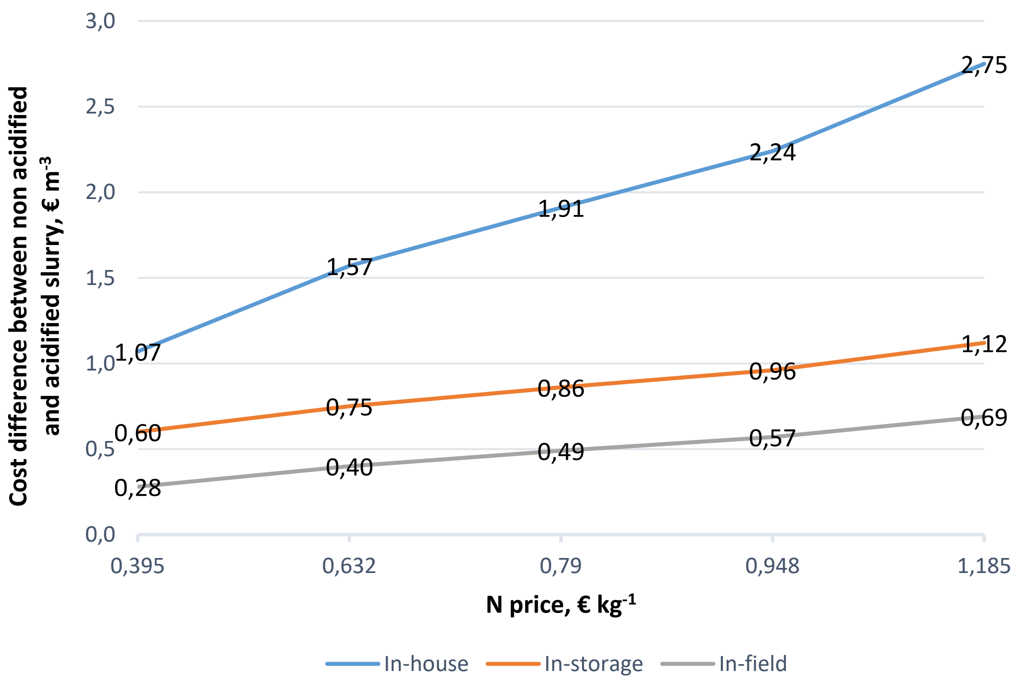

Figure 71. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

5.5.6. S price, Germany

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

S price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.08 € m^{-3}.	↑0.11 € m^{-3}.
in-storage SAT:	↑0.08 € m^{-3}.	↑0.08 € m^{-3}.
in-field SAT:	↑0.08 € m^{-3}	↑0.08 € m^{-3}.

Table 92. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.09	2.66	2.97	**0.31**	2.46	2.90	**0.44**	2.71	2.87	**0.16**
0.144	2.61	2.97	**0.36**	2.41	2.90	**0.49**	2.66	2.87	**0.21**
0.18	2.58	2.97	**0.39**	2.38	2.90	**0.52**	2.63	2.87	**0.24**
0.216	2.55	2.97	**0.42**	2.35	2.90	**0.55**	2.60	2.87	**0.27**
0.27	2.51	2.97	**0.46**	2.31	2.90	**0.59**	2.56	2.87	**0.31**

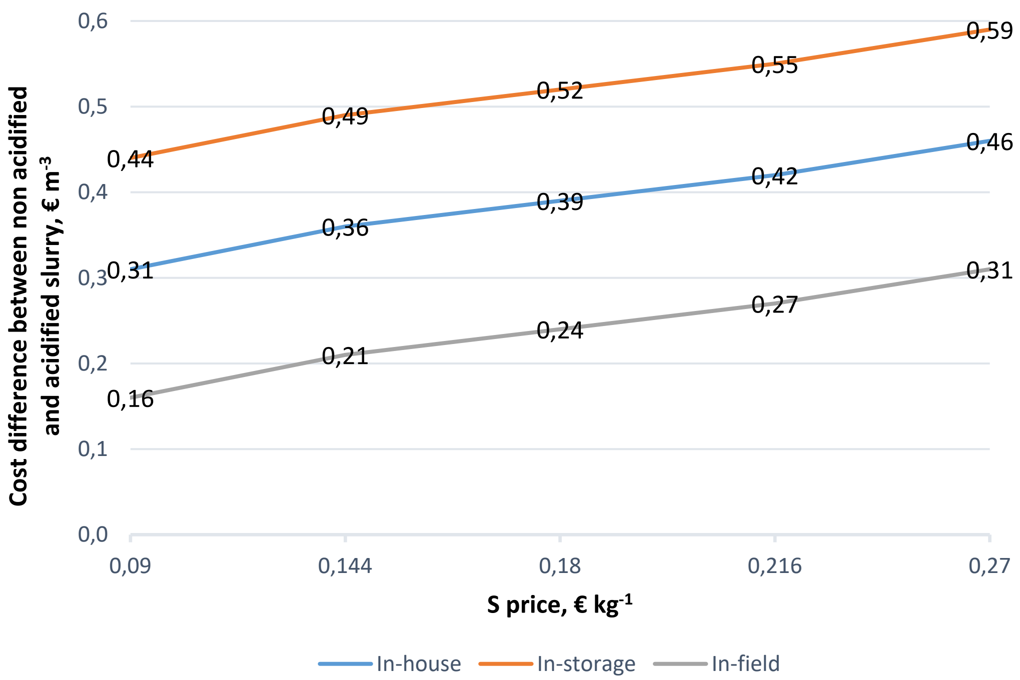

Figure 72. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

Table 93. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.09	1.45	3.26	**1.81**	2.14	2.92	**0.78**	2.48	2.89	**0.41**
0.144	1.39	3.26	**1.87**	2.09	2.92	**0.83**	2.43	2.89	**0.46**
0.18	1.35	3.26	**1.91**	2.06	2.92	**0.86**	2.40	2.89	**0.49**
0.216	1.31	3.26	**1.95**	2.03	2.92	**0.89**	2.37	2.89	**0.52**
0.27	1.26	3.26	**2.00**	1.99	2.92	**0.93**	2.33	2.89	**0.56**

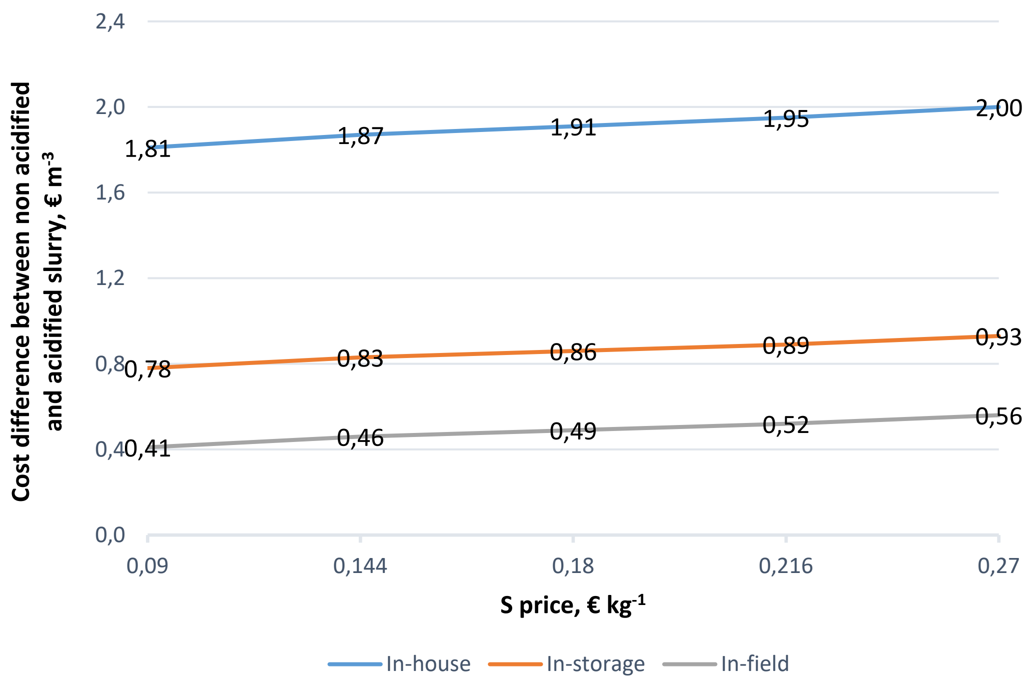

Figure 73. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

5.5.7. Summary, Germany

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. All three SATs have cost- benefit by cattle and pig slurry both in Germany.

The minimal slurry amounts should be between 3,100–13,100 and 2,200–9,700 m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 81).

Acidification of pig slurry has higher economic benefit compared to cattle slurry, because

5) pig slurry contains more NH_4-N to save
6) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry
7) the acid need of pig slurry is lower
8) the risk to exceed S need of plants is lower (because the acid amount is lower)

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) decreases if acid amount per cubicmeter increases. While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The acid price by in-house SAT (128 € m^{-3}) is lower than by other SATs (157 € m^{-3}) and this is the reason why change of acid amount has smaller effect on cost-benefit by first SAT compared to others.

The calculations in paragraph 5.5 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts (Figure 50) show that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1} .

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount reaches the demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount per hectare and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 64 and 65 show also that the order of cover types is same for both, cattle and big slurries.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises (see 5.5.4). N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises (see 5.5.5). The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises (see 5.5.6). The change of S price in mineral fertilisers has same impact by different SATs and slurry types, except bigger difference by pig slurry with in-house SAT.

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system. The analysis model will be available on project website.

5.6.Latvia

5.6.1. Annual slurry amount, Latvia

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The acid price in the calculations is 127 € t^{-1} for in-house acidification and 150 € t^{-1} for in-storage and in-field acidification. Minimum storage period 8 month. N-fertilisers is AN34.4, 230 € t^{-1}. NS-fertiliser N21-S24, 190 € t^{-1}. Thus N price 0.68 € kg^{-1} and S price 0.21 € kg^{-1}. The prices of project partner countries are between 0.48–1 and 0.11–0.85€ kg^{-1} respectively.

The cost-benfit of of slurry acidification in Latvia is relatively low. This is caused by low mineral N and S prices, and also relatively low slurry incorportion cost (23 € ha^{-1}). In-house acidification of cattle slurry hasn't cost-benefit by any slurry amount, in conditions used in the calculations.

The minimal slurry amounts should be between 8,000–31,100 and 3,500–12,400 m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 94).

Table 94. The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit.

SAT	Dairy cows: Annual slurry amount, m^3	Dairy cows: Number of animal	Fatteners: Annual slurry amount, m^3	Fatteners: Number of animal per year
In-house	NA	NA	6,971	13,942
In-storage	8,016	334	3,501	7,002
In-field	31,104	1,296	12,381	24,762

Table 95. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount m^3 yr^{-1}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1,200	10.66	6.09	**-4.57**	7.75	6.01	**-1.74**	11.87	5.98	**-5.89**
2,400	6.71	4.75	**-1.96**	5.33	4.67	**-0.66**	7.31	4.64	**-2.67**
9,000	3.40	2.98	**-0.42**	2.88	2.90	**0.02**	3.30	2.88	**-0.42**
12,000	2.92	2.70	**-0.22**	2.56	2.62	**0.06**	2.84	2.59	**-0.25**
21,000	2.33	2.23	**-0.10**	2.08	2.15	**0.07**	2.18	2.12	**-0.06**
24,000	2.19	2.13	**-0.06**	1.99	2.05	**0.06**	2.06	2.02	**-0.04**
33,000	1.97	1.91	**-0.06**	1.79	1.83	**0.04**	1.80	1.81	**0.01**
48,000	1.72	1.69	**-0.03**	1.60	1.61	**0.01**	1.57	1.59	**0.02**

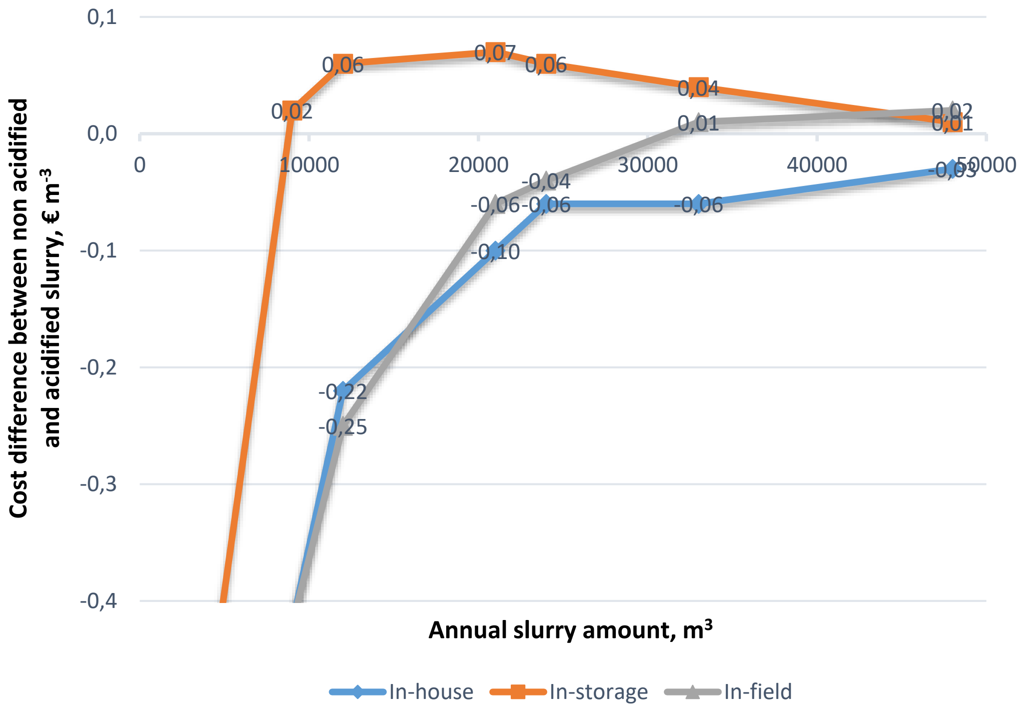

Figure 74. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Table 96. Fattener slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
500	33.55	8.65	**-24.90**	12.78	8.31	**-4.47**	22.99	8.28	**-14.71**
2,500	8.16	4.97	**-3.19**	4.91	4.63	**-0.28**	6.90	4.60	**-2.30**
5,000	4.48	3.95	**-0.53**	3.41	3.61	**0.20**	4.39	3.58	**-0.81**
9,000	2.82	3.27	**0.45**	2.57	2.93	**0.36**	3.09	2.90	**-0.19**
21,000	1.37	2.52	**1.15**	1.77	2.18	**0.41**	1.97	2.15	**0.18**
33,000	0.91	2.20	**1.29**	1.48	1.86	**0.38**	1.59	1.83	**0.24**

Figure 75. The cost decrease (€ m^{-3}) by use of fattener slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

5.6.2. Cover type, Latvia

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. In-house acidification of cattle slurry has positive cost-benefit only compared to these three cover types . Compared to the Hexa-cover plates and Fibo clay balls gives slurry acidification lowest cost benefit by cattle slurry. By pig slurry is cost-benefit lowest by Hexa-cover plates and floating foil.

In Latvia, the required minimum manure storage capacity is 8 months. In this analysis is presumed that animal are housed in all year around and storage depth is 5 m. The capital cost of slurry storage cover calculated for these conditions are shown in the table 21.

Table 97. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different

type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	Acid	In-house No acid	**Dif.**
No cover	2.33	2.23	**-0.10**
Chopped straw	2.51	2.28	**-0.23**
Fibo clay balls (fraction 10-20 mm)	2.55	2.30	**-0.25**
Floating foil	2.56	2.32	**-0.24**
Hexa-cover plates	2.57	2.32	**-0.25**
Peat	2.56	2.61	**0.05**
Rapeseed oil	2.55	3.17	**0.62**
Tent cover	2.59	2.68	**0.09**

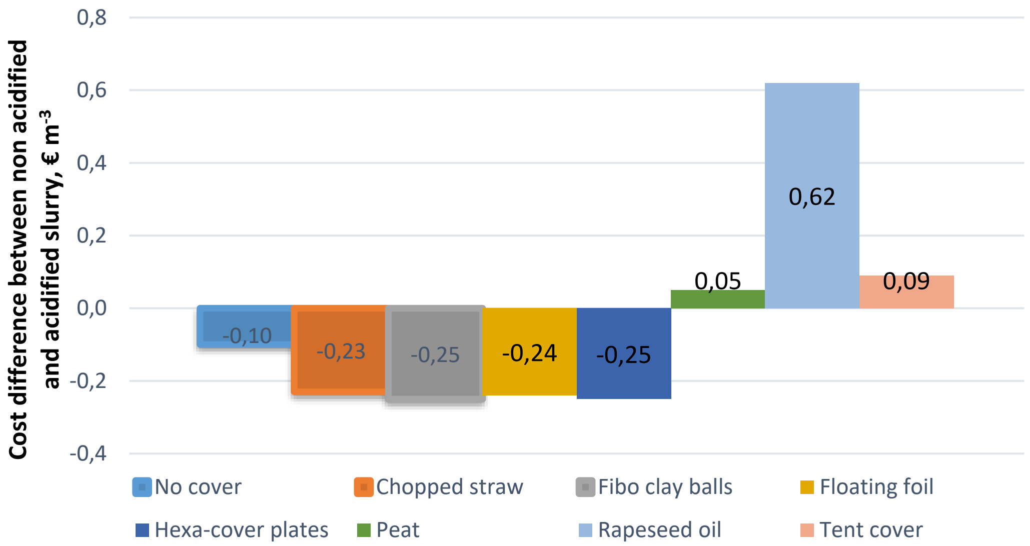

Figure 76. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Table 98. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	Acid	In-house No acid	**Dif.**
No cover	1.37	2.52	**1.15**
Chopped straw	1.60	2.55	**0.95**
Fibo clay balls (fraction 10-20 mm)	1.65	2.57	**0.92**
Floating foil	1.67	2.58	**0.91**

Hexa-cover plates	1.68	2.59	**0.91**
Peat	1.67	2.87	**1.20**
Rapeseed oil	1.65	3.44	**1.79**
Tent cover	1.70	2.94	**1.24**

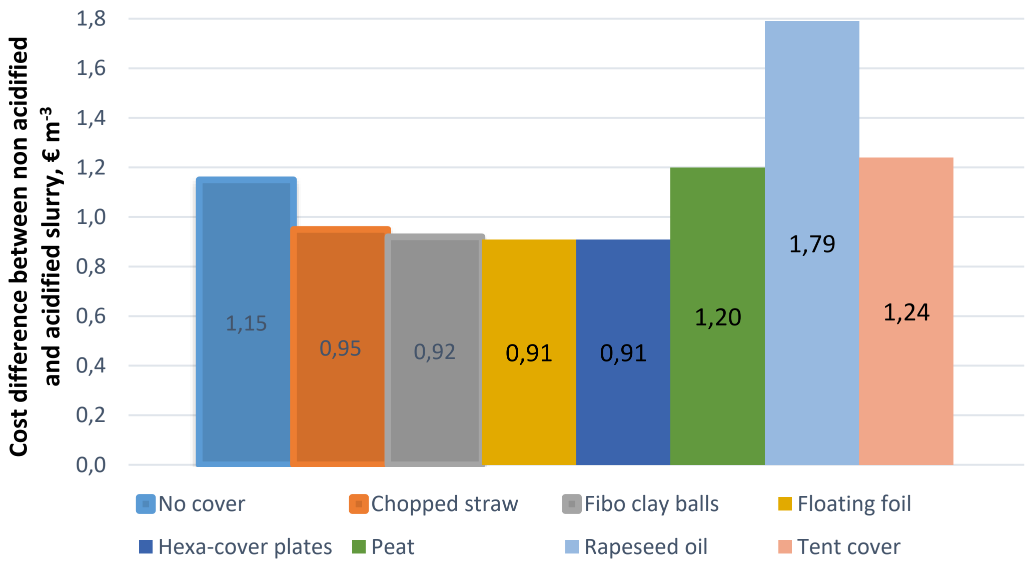

Figure 77. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners.

5.6.3. Acid consumption, Latvia

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) decreases if acid amount per cubicmeter increases.

If acid consumption ↑ 1 l m^{-3}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↓0.32 € m^{-3}	↓0.31 € m^{-3}
in-storage SAT:	↓0.36 € m^{-3}	↓0.36 € m^{-3}
in-field SAT:	↓0.38 € m^{-3}	↓0.38 € m^{-3}

Acid content change in slurry has lowest impact by in-house SAT and biggest by in-field SAT. The reason is that the acid price for in-house SAT is lower (127 € t^{-1}) than by other SATs (150 € t^{-1}).

Table 99. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	1.25	2.23	**0.98**	1.18	2.15	**0.97**	1.48	2.12	**0.64**
3	1.83	2.23	**0.40**	1.85	2.15	**0.30**	2.18	2.12	**-0.06**
4	2.16	2.23	**0.07**	2.23	2.15	**-0.08**	2.57	2.12	**-0.45**
5	2.49	2.23	**-0.26**	2.61	2.15	**-0.46**	2.96	2.12	**-0.84**
7	3.15	2.23	**-0.92**	3.36	2.15	**-1.21**	3.73	2.12	**-1.61**

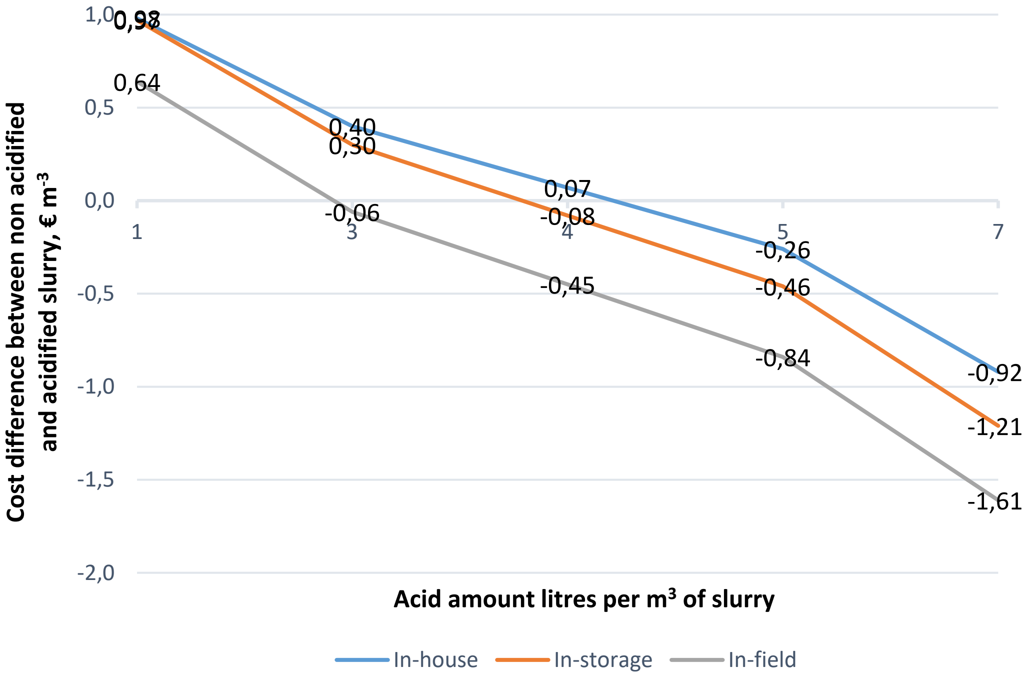

Figure 78. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

Table 100. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	0.68	2.52	**1.84**	1.09	2.18	**1.09**	1.41	2.15	**0.74**
3	1.21	2.52	**1.31**	1.77	2.18	**0.41**	2.11	2.15	**0.04**
4	1.54	2.52	**0.98**	2.14	2.18	**0.04**	2.50	2.15	**-0.35**
5	1.87	2.52	**0.65**	2.52	2.18	**-0.34**	2.89	2.15	**-0.74**
7	2.53	2.52	**-0.01**	3.27	2.18	**-1.09**	3.66	2.15	**-1.51**

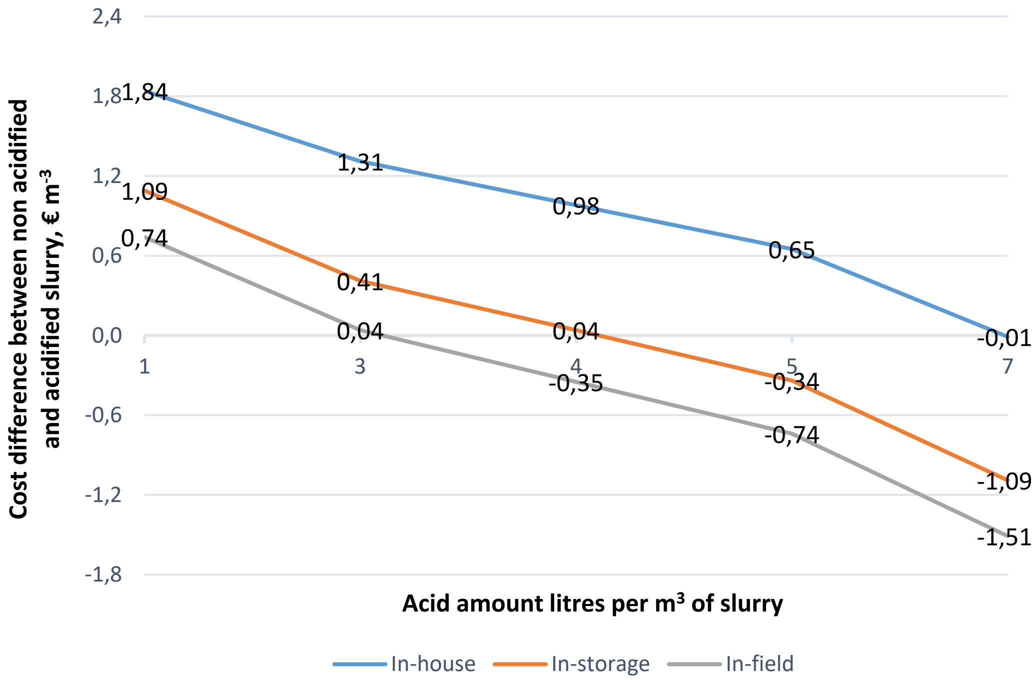

Figure 79. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

5.6.4. N_{tot} in slurry, Latvia

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

If N_{tot} content in slurry ↑ 1 kg m^{-3} , then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.21 € m^{-3}.	↑0.29 € m^{-3}.
in-storage SAT:	↑0.12 € m^{-3}.	↑0.12 € m^{-3}.
in-field SAT:	↑0.10 € m^{-3}	↑0.09 € m^{-3}.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.

Table 101. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content	In-house			In-storage			In-field		
kg m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
3				2.21	2.11	**-0.10**	2.28	2.09	**-0.19**
4	2.64	2.13	**-0.51**	2.12	2.13	**0.01**	2.22	2.11	**-0.11**

5	2.43	2.20	**-0.23**	2.04	2.16	**0.12**	2.15	2.13	**-0.02**
6	2.32	2.23	**-0.09**	1.95	2.19	**0.24**	2.08	2.16	**0.08**
7	2.21	2.27	**0.06**						

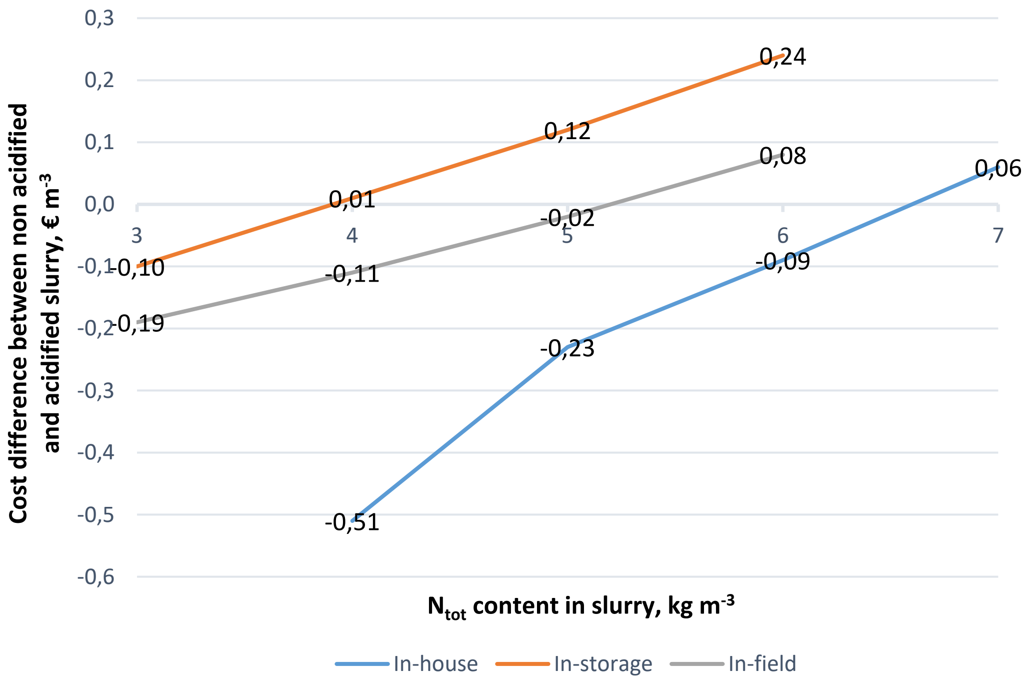

Figure 80. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Table 102. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
4				1.90	2.13	**0.23**	2.07	2.11	**0.04**
5	1.81	2.38	**0.57**	1.81	2.16	**0.35**	2.00	2.13	**0.13**
6	1.59	2.45	**0.86**	1.73	2.19	**0.46**	1.93	2.16	**0.23**
7	1.37	2.52	**1.15**	1.64	2.22	**0.58**	1.87	2.18	**0.31**
8	1.16	2.59	**1.43**						

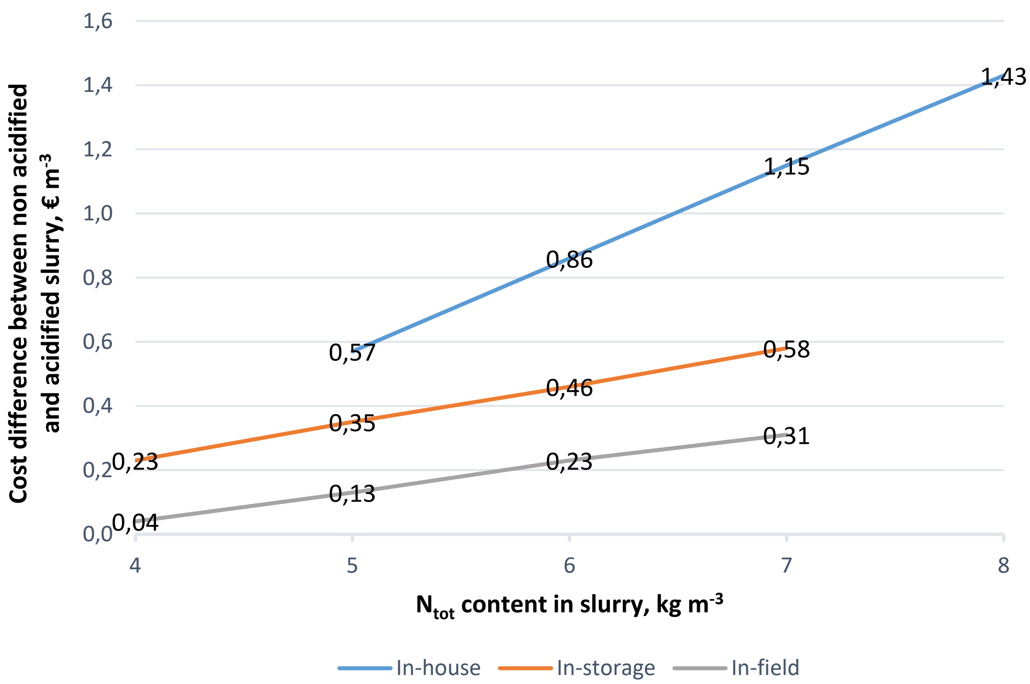

Figure 81. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

5.6.5. N price, Latvia

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises.

N price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.088 € m^{-3}.	↑0.21 € m^{-3}.
in-storage SAT:	↑0.054 € m^{-3}.	↑0.07 € m^{-3}.
in-field SAT:	↑0.043 € m^{-3}	↑0.05 € m^{-3}.

The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.
Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

Table 103. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.335	2.62	2.23	**-0.39**	2.26	2.15	**-0.11**	2.32	2.12	**-0.20**

0.536	2.44	2.23	**-0.21**	2.15	2.15	**0.00**	2.24	2.12	**-0.12**
0.67	2.32	2.23	**-0.09**	2.08	2.15	**0.07**	2.18	2.12	**-0.06**
0.804	2.21	2.23	**0.02**	2.00	2.15	**0.15**	2.12	2.12	**0.00**
1.005	2.03	2.23	**0.20**	1.90	2.15	**0.25**	2.03	2.12	**0.09**

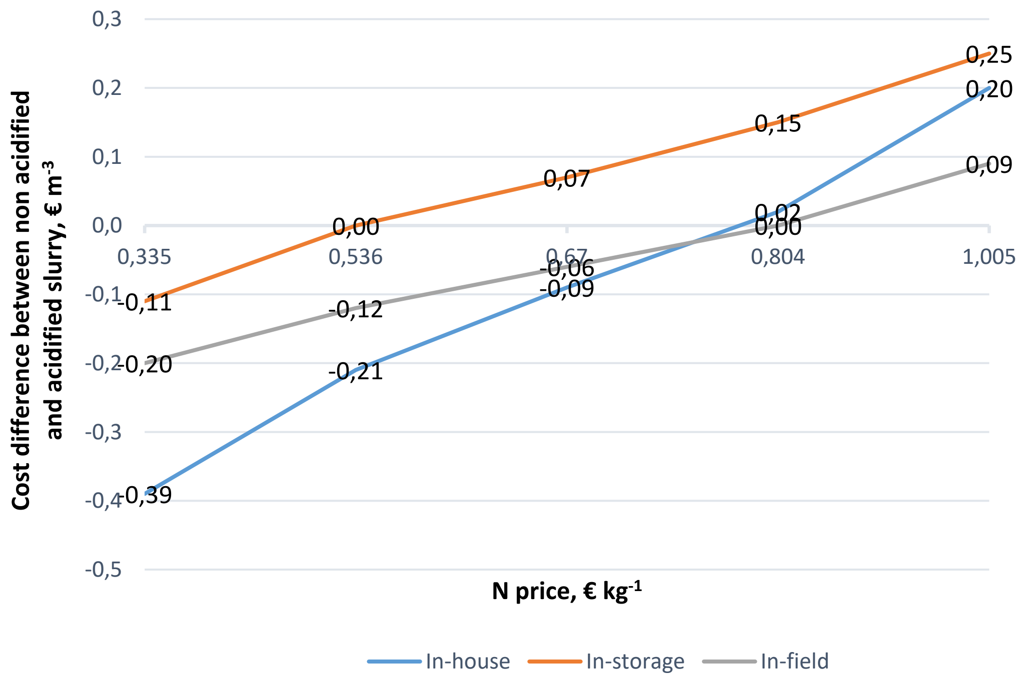

Figure 82. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

Table 104. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.335	2.08	2.52	**0.44**	1.99	2.18	**0.19**	2.14	2.15	**0.01**
0.536	1.65	2.52	**0.87**	1.85	2.18	**0.33**	2.04	2.15	**0.11**
0.67	1.37	2.52	**1.15**	1.76	2.18	**0.42**	1.97	2.15	**0.18**
0.804	1.08	2.52	**1.44**	1.68	2.18	**0.50**	1.89	2.15	**0.26**
1.005	0.66	2.52	**1.86**	1.54	2.18	**0.64**	1.79	2.15	**0.36**

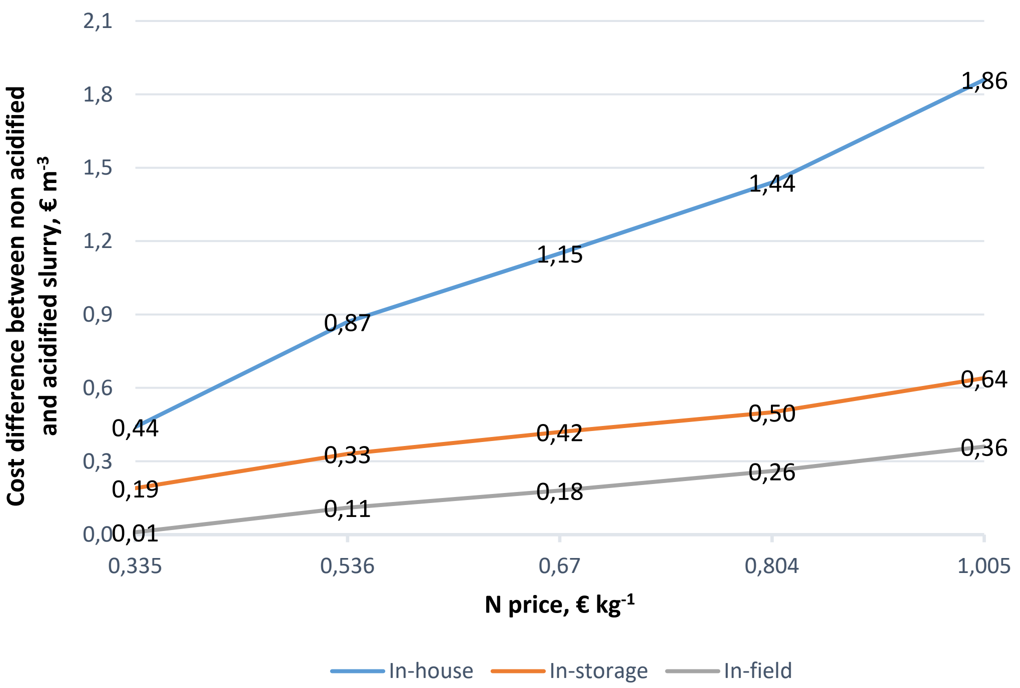

Figure 83. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

5.6.6. S price, Latvia

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

S price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-pit SAT:	↑0.08 € m^{-3}.	↑0.10 € m^{-3}.
in-storage SAT:	↑0.08 € m^{-3}.	↑0.08 € m^{-3}.
in-field SAT:	↑0.09 € m^{-3}	↑0.08 € m^{-3}.

Table 105. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.105	2.41	2.23	**-0.18**	2.16	2.15	**-0.01**	2.27	2.12	**-0.15**
0.168	2.36	2.23	**-0.13**	2.11	2.15	**0.04**	2.21	2.12	**-0.09**
0.21	2.32	2.23	**-0.09**	2.08	2.15	**0.07**	2.18	2.12	**-0.06**
0.252	2.29	2.23	**-0.06**	2.04	2.15	**0.11**	2.14	2.12	**-0.02**
0.315	2.24	2.23	**-0.01**	1.99	2.15	**0.16**	2.09	2.12	**0.03**

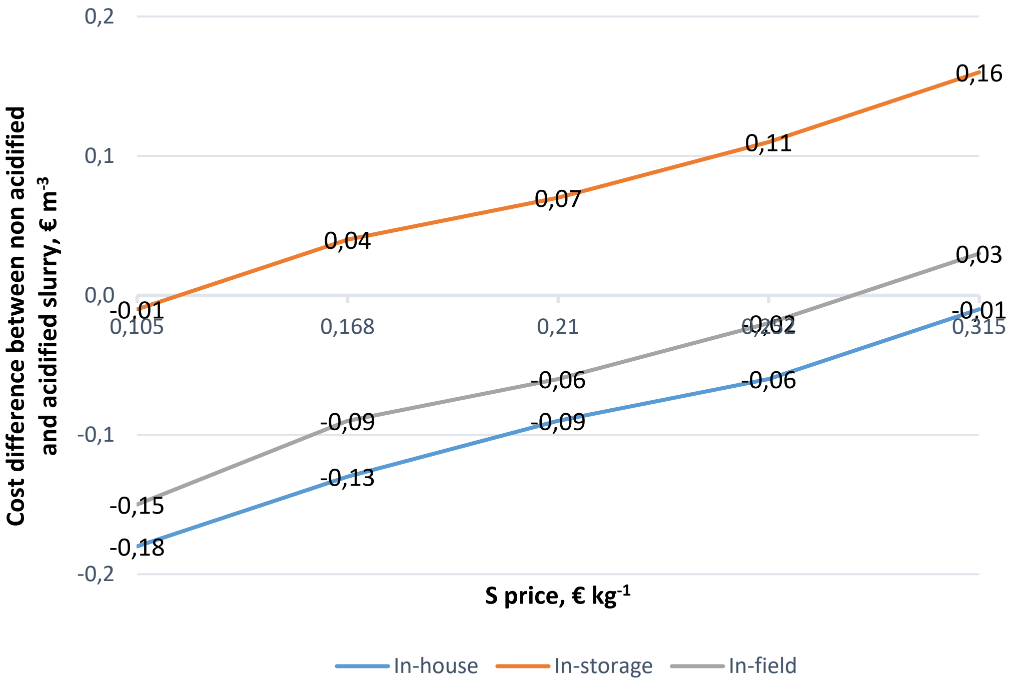

Figure 84. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

Table 106. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.105	1.48	2.52	**1.04**	1.85	2.18	**0.33**	2.05	2.15	**0.10**
0.168	1.41	2.52	**1.11**	1.80	2.18	**0.38**	2.00	2.15	**0.15**
0.21	1.37	2.52	**1.15**	1.76	2.18	**0.42**	1.97	2.15	**0.18**
0.252	1.32	2.52	**1.20**	1.73	2.18	**0.45**	1.93	2.15	**0.22**
0.315	1.26	2.52	**1.26**	1.68	2.18	**0.50**	1.88	2.15	**0.27**

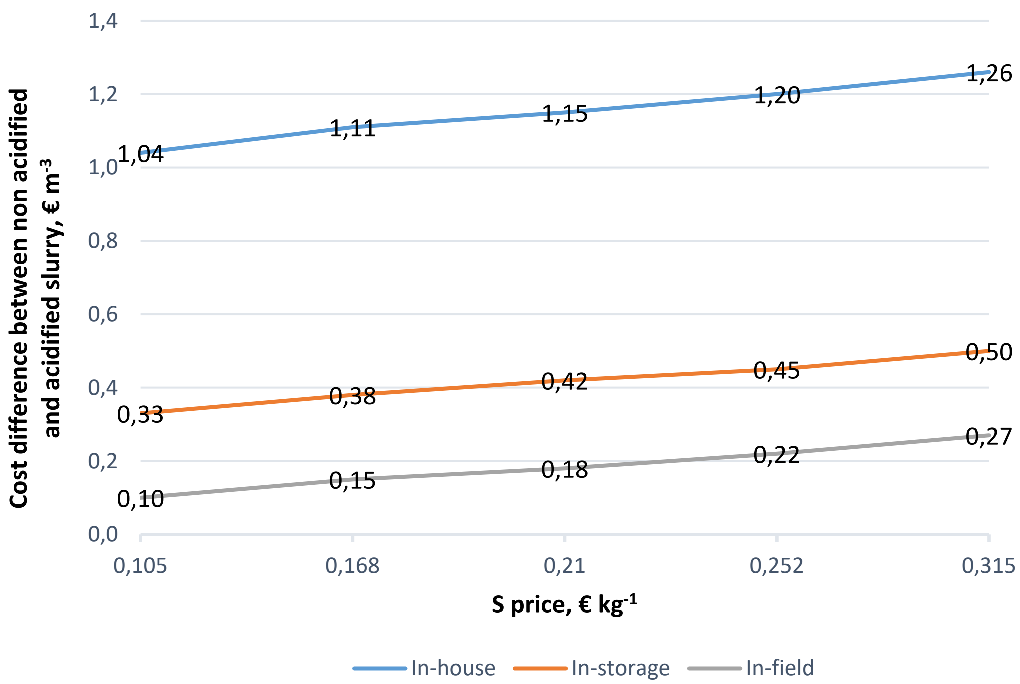

Figure 85. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

5.6.7. Summary, Latvia

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The cost-benfit of of slurry acidification in Latvia is relatively low. This is caused by low mineral N and S prices, and also relatively low slurry incorportion cost (23 € ha^{-1}). In-house acidification of cattle slurry hasn't cost-benefit by any slurry amount, in conditions used in the calculations.

The minimal slurry amounts should be between 8,000–31,100 and 3,500–12,400 m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 94).

Acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save
2) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry
3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower)

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) decreases if acid amount per cubicmeter increases. While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The acid price by in-house

SAT (127 € m^{-3}) is lower than by other SATs (150 € m^{-3}) and this is the reason why change of acid amount has smaller effect on cost-benefit by first SAT compared to others.

The calculations in paragraph 5.6 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts (Figure 50) show that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1} .

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount reaches the demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount per hectare and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. In-house acidification of cattle slurry has positive cost-benefit only compared to these three cover types . Compared to the Hexa-cover plates and Fibo clay balls gives slurry acidification lowest cost benefit by cattle slurry. By pig slurry is cost-benefit lowest by Hexa-cover plates and floating foil.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises (see 5.6.4). N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises (see 5.6.5). The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises (see 5.6.6).

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system. The analysis model will be available on project website

5.7. Lithuania

5.7.1. Annual slurry amount, Lithuania

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The acid price in the calculations is 128 € t^{-1} for in-house acidification and 157 € t^{-1} for in-storage and in-field acidification. Minimum storage period 6 month. N-fertilisers is AN34.4, 250 € t^{-1}. NS-fertiliser N21-S24, 200 € t^{-1}. Thus N price 0.73 € kg^{-1} and S price 0.15 € kg^{-1}. The prices of project partner countries are between 0.48–1 and 0.11–0.85€ kg^{-1} respectively.

Table 107. The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit.

SAT	Dairy cows: Annual slurry amount, m^3	Dairy cows: Number of animal	Fatteners: Annual slurry amount, m^3	Fatteners: Number of animal per year
In-house	NA	NA	4,564	9,127
In-storage	NA	NA	3,226	6,451
In-field	NA	NA	10,827	21,653

The calculation results show, that in Lithuania by all cattle slurry amounts, if slurry is acidified, then costs are higher than by non-acidified but incorporated slurry. The reason is mainly very high liming costs - 175 € t^{-1} for liming service including liming material and transport. Another reason is relatively low S price compared to other project countries (0.15 € kg^{-1} and 0.11–0.85 € kg^{-1}) .

The minimal pig slurry amounts should be between 3,200–10,800 m^3 yearly depending on SAT (see Table 107).

Table 108. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount m^3 yr^{-1}	In-house: Acid	In-house: No acid	In-house: **Dif.**	In-storage: Acid	In-storage: No acid	In-storage: **Dif.**	In-field: Acid	In-field: No acid	In-field: **Dif**
1,200	11.26	6.63	**-4.63**	8.28	6.39	**-1.89**	12.10	6.32	**-5.78**
2,400	7.31	5.31	**-2.00**	5.83	5.06	**-0.77**	7.63	4.99	**-2.64**
9,000	4.02	3.53	**-0.49**	3.38	3.29	**-0.09**	3.69	3.21	**-0.48**
12,000	3.54	3.24	**-0.30**	3.06	3.00	**-0.06**	3.24	2.93	**-0.31**
21,000	2.97	2.77	**-0.20**	2.59	2.52	**-0.07**	2.59	2.45	**-0.14**
24,000	2.83	2.66	**-0.17**	2.50	2.42	**-0.08**	2.47	2.35	**-0.12**
33,000	2.61	2.44	**-0.17**	2.30	2.20	**-0.10**	2.23	2.13	**-0.10**
48,000	2.37	2.21	**-0.16**	2.12	1.97	**-0.15**	1.99	1.90	**-0.09**

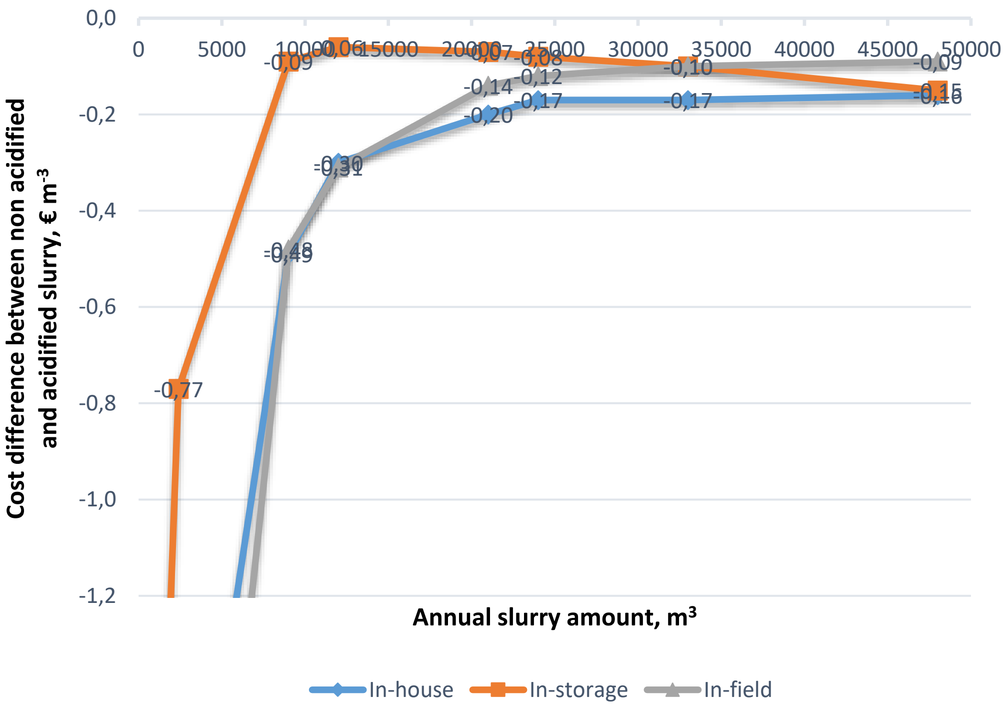

Figure 86. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Table 109. Fattener slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry depending on number of animal.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
500	33.62	9.73	**-23.89**	13.26	8.70	**-4.56**	22.90	8.61	**-14.29**
2.500	8.48	6.11	**-2.37**	5.30	5.08	**-0.22**	7.14	4.99	**-2.15**
5.000	4.84	5.09	**0.25**	3.81	4.09	**0.28**	4.67	3.97	**-0.70**
9.000	3.19	4.40	**1.21**	2.96	3.37	**0.41**	3.39	3.28	**-0.11**
21.000	1.77	3.63	**1.86**	2.17	2.61	**0.44**	2.30	2.52	**0.22**
33.000	1.31	3.31	**2.00**	1.89	2.29	**0.40**	1.93	2.19	**0.26**

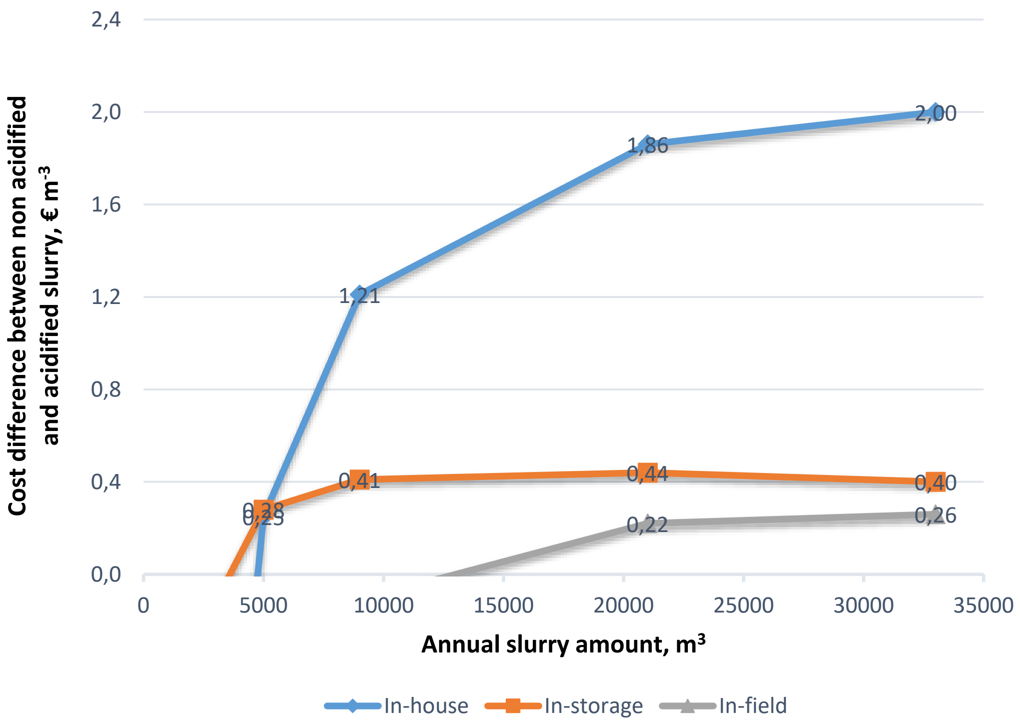

Figure 87 The cost decrease (€ m^{-3}) by use of fattener slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

5.7.2. Cover type, Lithuania

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. In-house acidification of cattle slurry has positive cost-benefit only compared to tent cover. In-house acidification of pig slurry has positive cost-benefit compared to all cover types.

In Lithuania, the required minimum manure storage capacity is 6 months. In this analysis is presumed that animal are housed in all year around and storage depth is 5 m. The capital cost of slurry storage cover calculated for these conditions are shown in the table 21.

Table 110. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	Acid	In-house No acid	**Dif.**
No cover	2.97	2.77	**-0.20**
Chopped straw	3.16	2.67	**-0.49**
Fibo clay balls (fraction 10-20 mm)	3.20	2.66	**-0.54**
Floating foil	3.22	2.66	**-0.56**
Hexa-cover plates	3.23	2.66	**-0.57**
Peat	3.22	2.88	**-0.34**
Rapeseed oil	3.20	3.31	**0.11**
Tent cover	3.25	2.91	**-0.34**

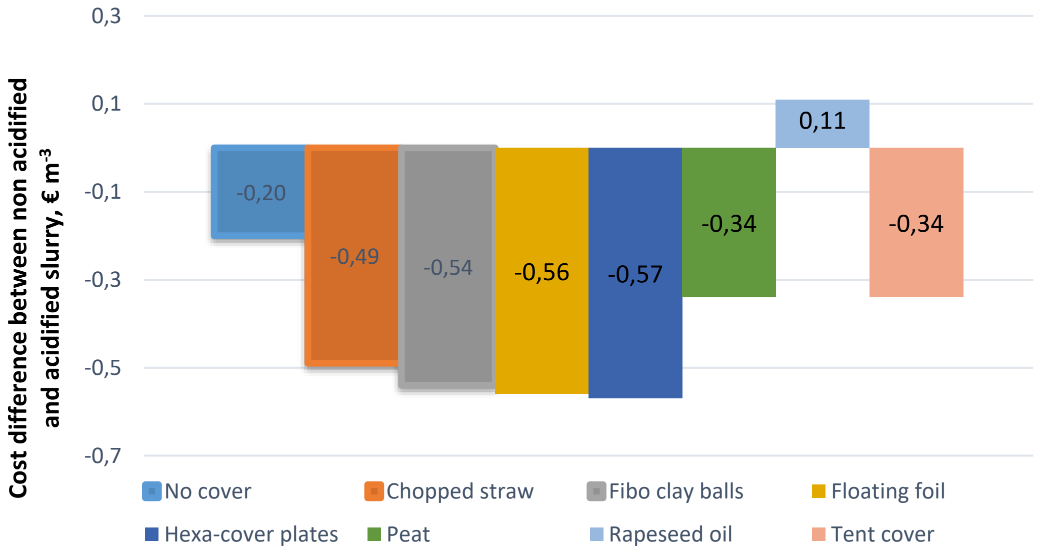

Figure 88. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Table 111. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	Acid	In-house No acid	**Dif.**
No cover	1.77	3.63	**1.86**
Chopped straw	2.01	3.50	**1.49**
Fibo clay balls (fraction 10-20 mm)	2.07	3.47	**1.40**
Floating foil	2.08	3.47	**1.39**
Hexa-cover plates	2.10	3.46	**1.36**
Peat	2.08	3.69	**1.61**

Rapeseed oil	2.07	4.13	**2.06**
Tent cover	2.12	3.71	**1.59**

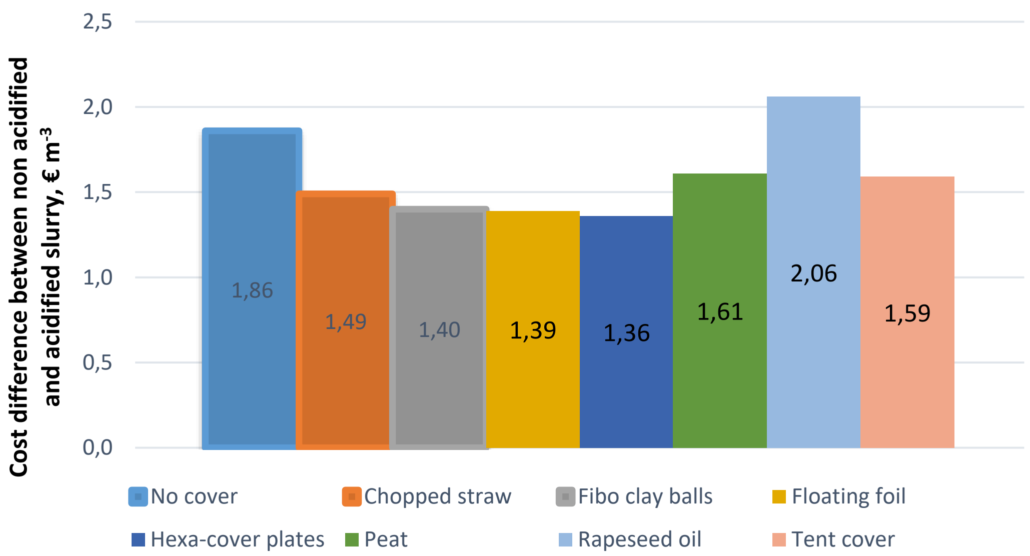

Figure 89. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners.

5.7.3. Acid consumption, Lithuania

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) decreases if acid amount per cubicmeter increases.

If acid consumption ↑ 1 l m^{-3}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↓0.48 € m^{-3}	↓0.47 € m^{-3}
in-storage SAT:	↓0.53 € m^{-3}	↓0.53 € m^{-3}
in-field SAT:	↓0.54 € m^{-3}	↓0.54 € m^{-3}

Acid content change in slurry has lowest impact by in-house SAT and biggest by in-field SAT. The reason is that the acid price for in-house SAT is lower (128 € t^{-1}) than by other SATs (157 € t^{-1}).

Table 112. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount	In-house			In-storage			In-field		
l m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**

1	1.31	2.77	**1.46**	1.26	2.52	**1.26**	1.56	2.45	**0.89**
3	2.22	2.77	**0.55**	2.27	2.52	**0.25**	2.59	2.45	**-0.14**
4	2.72	2.77	**0.05**	2.81	2.52	**-0.29**	3.14	2.45	**-0.69**
5	3.21	2.77	**-0.44**	3.35	2.52	**-0.83**	3.70	2.45	**-1.25**
7	4.20	2.77	**-1.43**	4.42	2.52	**-1.90**	4.80	2.45	**-2.35**

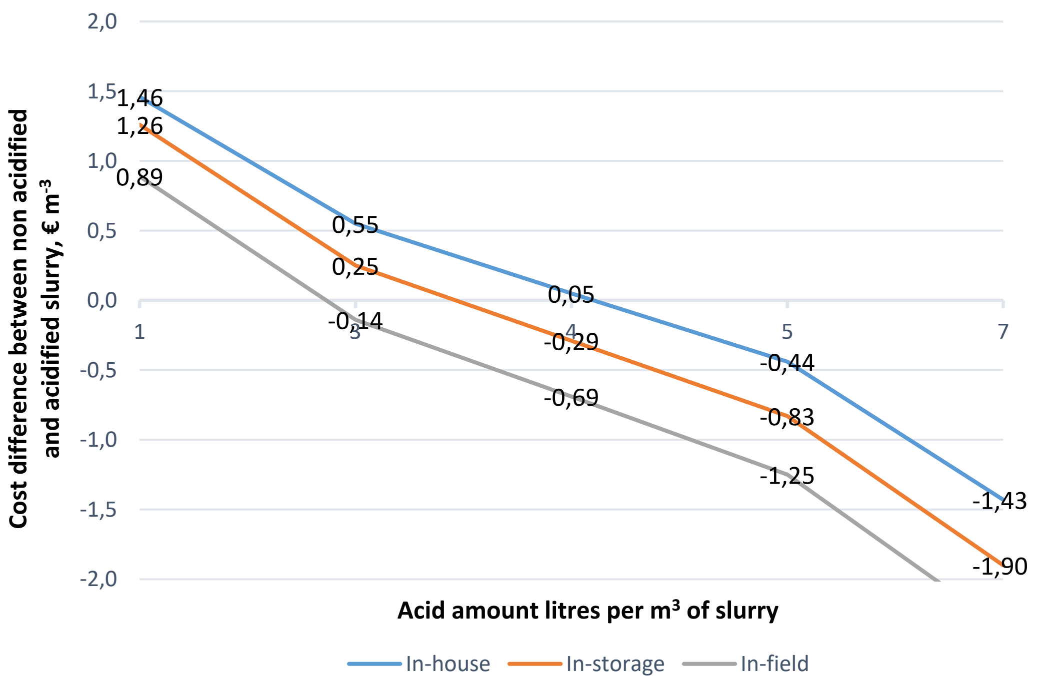

Figure 90. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

Table 113. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	0.67	3.63	**2.96**	1.17	2.61	**1.44**	1.49	2.52	**1.03**
3	1.52	3.63	**2.11**	2.17	2.61	**0.44**	2.52	2.52	**0.00**
4	2.02	3.63	**1.61**	2.71	2.61	**-0.10**	3.07	2.52	**-0.55**
5	2.51	3.63	**1.12**	3.25	2.61	**-0.64**	3.62	2.52	**-1.10**
7	3.50	3.63	**0.13**	4.33	2.61	**-1.72**	4.72	2.52	**-2.20**

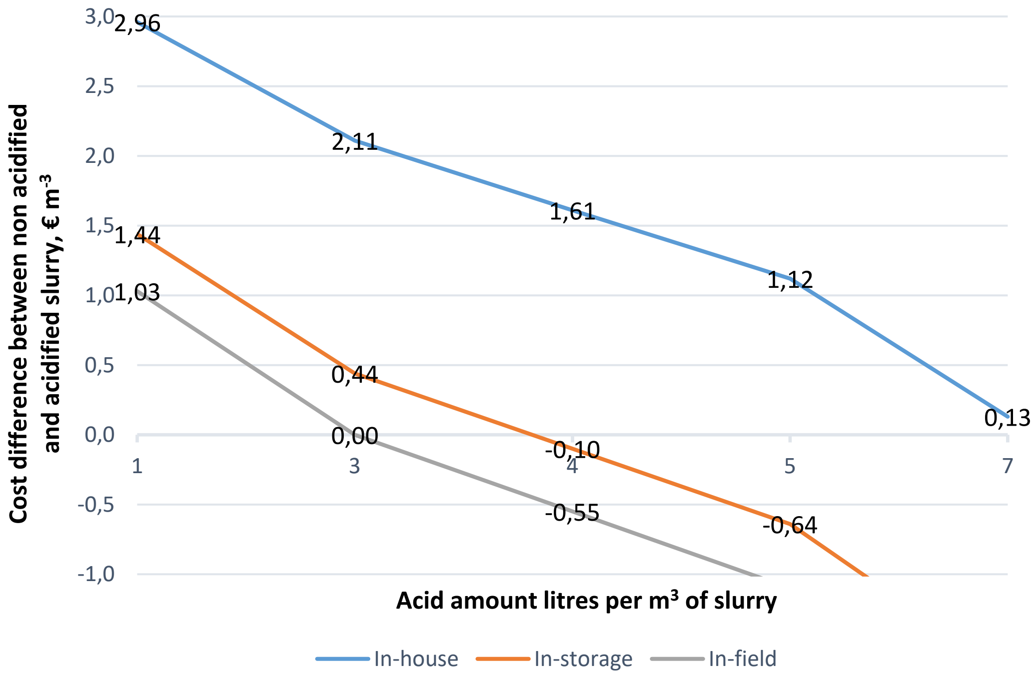

Figure 91. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

5.7.4. N_{tot} in slurry, Lithuania

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

If N_{tot} content in slurry ↑ 1 kg m^{-3} , then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.23 € m^{-3}.	↑0.45 € m^{-3}.
in-storage SAT:	↑0.18 € m^{-3}.	↑0.18 € m^{-3}.
in-field SAT:	↑0.15 € m^{-3}	↑0.15 € m^{-3}.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.

Table 114. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
3				2.72	2.40	**-0.32**	2.70	2.35	**-0.35**
4	3.19	2.57	**-0.62**	2.63	2.48	**-0.15**	2.63	2.41	**-0.22**

5	3.07	2.67	**-0.40**	2.54	2.57	**0.03**	2.56	2.48	**-0.08**
6	2.95	2.78	**-0.17**	2.45	2.65	**0.20**	2.48	2.55	**0.07**
7	2.84	2.88	**0.04**						

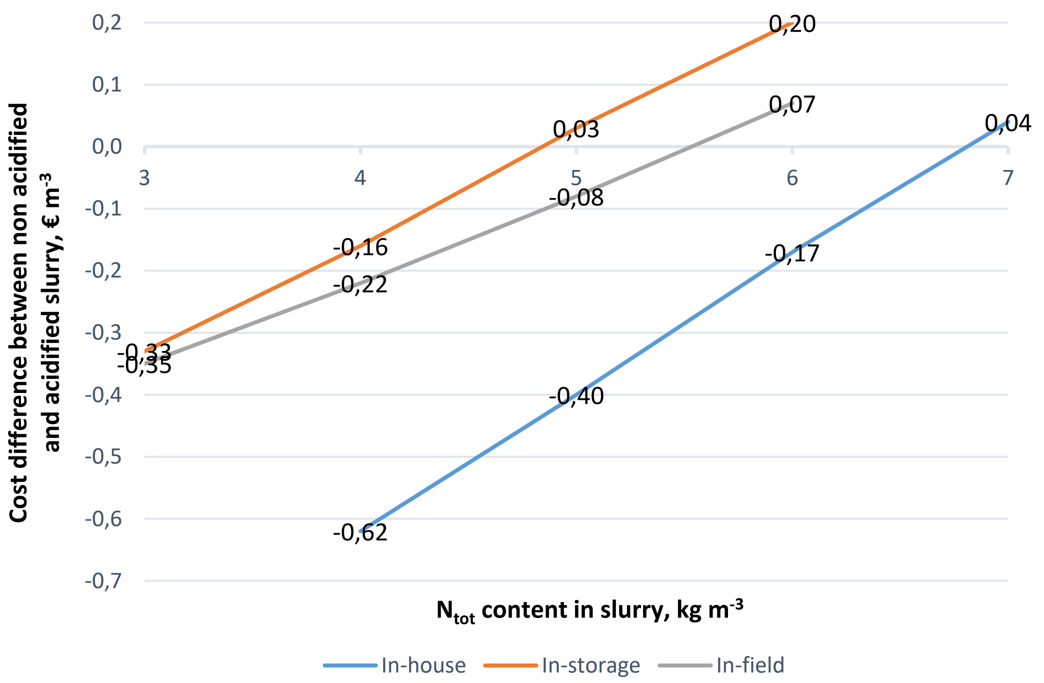

Figure 92. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Table 115. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
4				2.31	2.48	**0.17**	2.41	2.41	**0.00**
5	2.24	3.21	**0.97**	2.22	2.57	**0.35**	2.34	2.48	**0.14**
6	2.00	3.42	**1.42**	2.13	2.56	**0.43**	2.26	2.55	**0.29**
7	1.77	3.63	**1.86**	2.03	2.73	**0.70**	2.19	2.62	**0.43**
8	1.53	3.85	**2.32**						

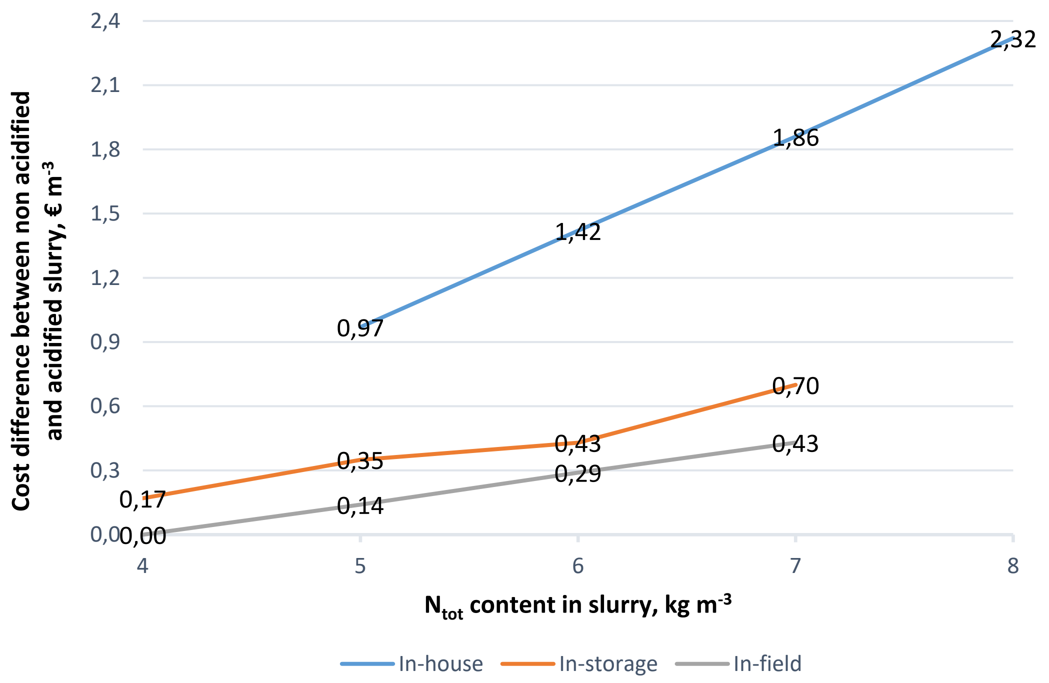

Figure 93. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

5.7.5. N price, Lithuania

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises.

N price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.088 € m^{-3}.	↑0.21 € m^{-3}.
in-storage SAT:	↑0.053 € m^{-3}.	↑0.07 € m^{-3}.
in-field SAT:	↑0.044 € m^{-3}	↑0.05 € m^{-3}.

The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.
Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

Table 116. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.365	3.28	2.77	**-0.51**	2.78	2.52	**-0.26**	2.75	2.45	**-0.30**

0.584	3.09	2.77	**-0.32**	2.66	2.52	**-0.14**	2.65	2.45	**-0.20**
0.73	2.96	2.77	**-0.19**	2.59	2.52	**-0.07**	2.59	2.45	**-0.14**
0.876	2.83	2.77	**-0.06**	2.51	2.52	**0.01**	2.53	2.45	**-0.08**
1.095	2.64	2.77	**0.13**	2.39	2.52	**0.13**	2.43	2.45	**0.02**

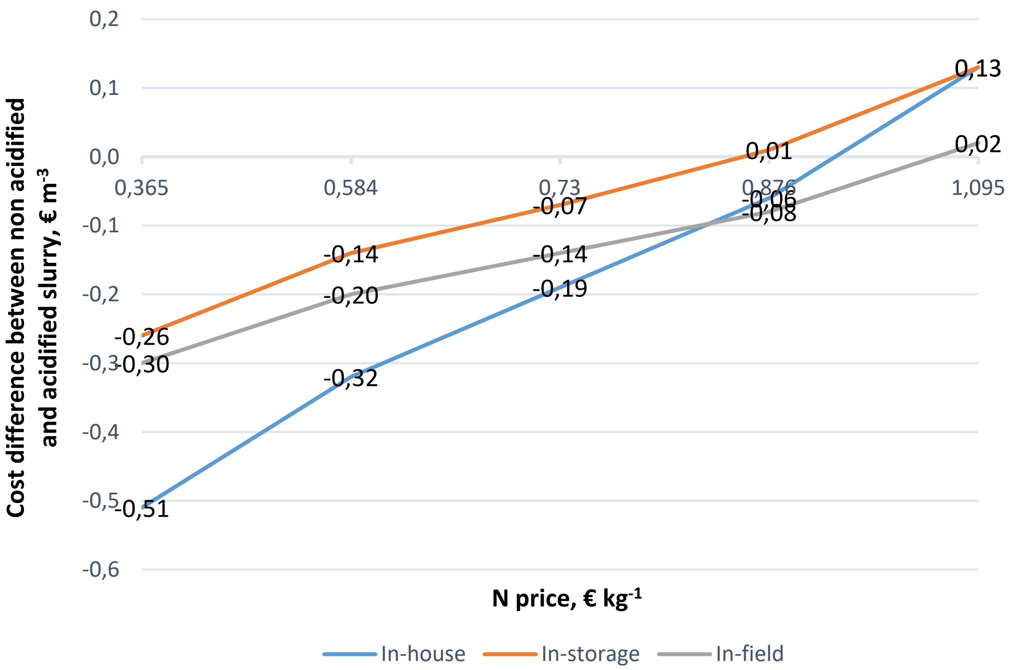

Figure 94. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

Table 117. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.365	2.53	3.63	**1.10**	2.41	2.61	**0.20**	2.49	2.52	**0.03**
0.584	2.07	3.63	**1.56**	2.26	2.61	**0.35**	2.37	2.52	**0.15**
0.73	1.76	3.63	**1.87**	2.17	2.61	**0.44**	2.29	2.52	**0.23**
0.876	1.45	3.63	**2.18**	2.07	2.61	**0.54**	2.22	2.52	**0.30**
1.095	0.98	3.63	**2.65**	1.93	2.61	**0.68**	2.10	2.52	**0.42**

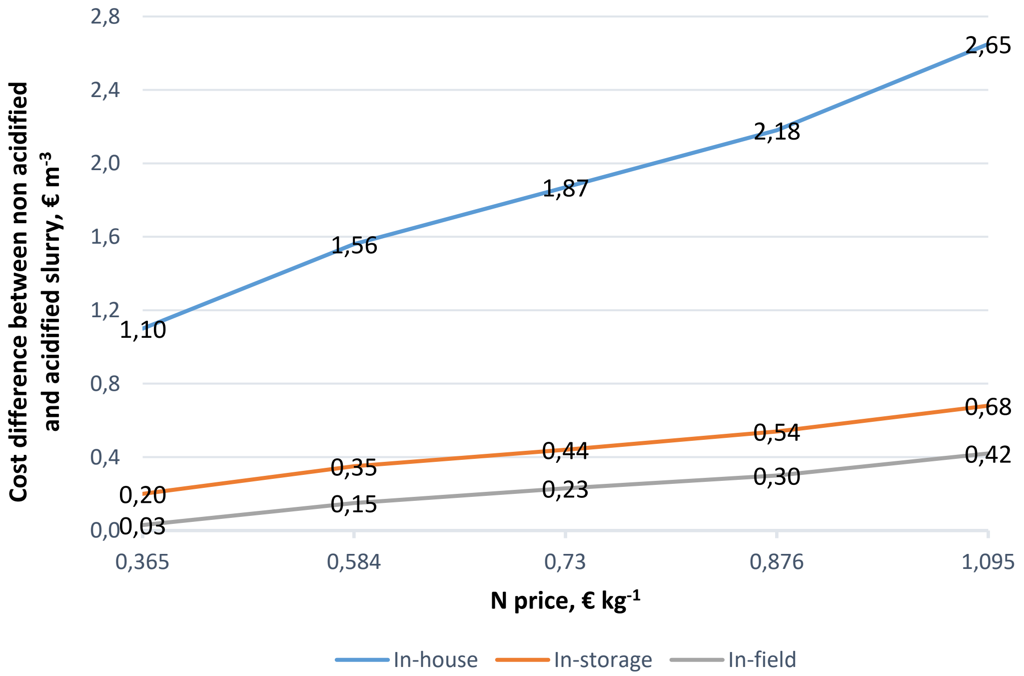

Figure 95. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

5.7.6. S price, Lithuania

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

S price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-pit SAT:	↑0.08 € m^{-3}.	↑0.11 € m^{-3}.
in-storage SAT:	↑0.09 € m^{-3}.	↑0.08 € m^{-3}.
in-field SAT:	↑0.08 € m^{-3}	↑0.09 € m^{-3}.

Table 118. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.1	3.04	2.77	**-0.27**	2.67	2.52	**-0.15**	2.67	2.45	**-0.22**
0.16	2.99	2.77	**-0.22**	2.62	2.52	**-0.10**	2.62	2.45	**-0.17**
0.2	2.96	2.77	**-0.19**	2.59	2.52	**-0.07**	2.59	2.45	**-0.14**
0.24	2.93	2.77	**-0.16**	2.55	2.52	**-0.03**	2.56	2.45	**-0.11**
0.3	2.88	2.77	**-0.11**	2.50	2.52	**0.02**	2.51	2.45	**-0.06**

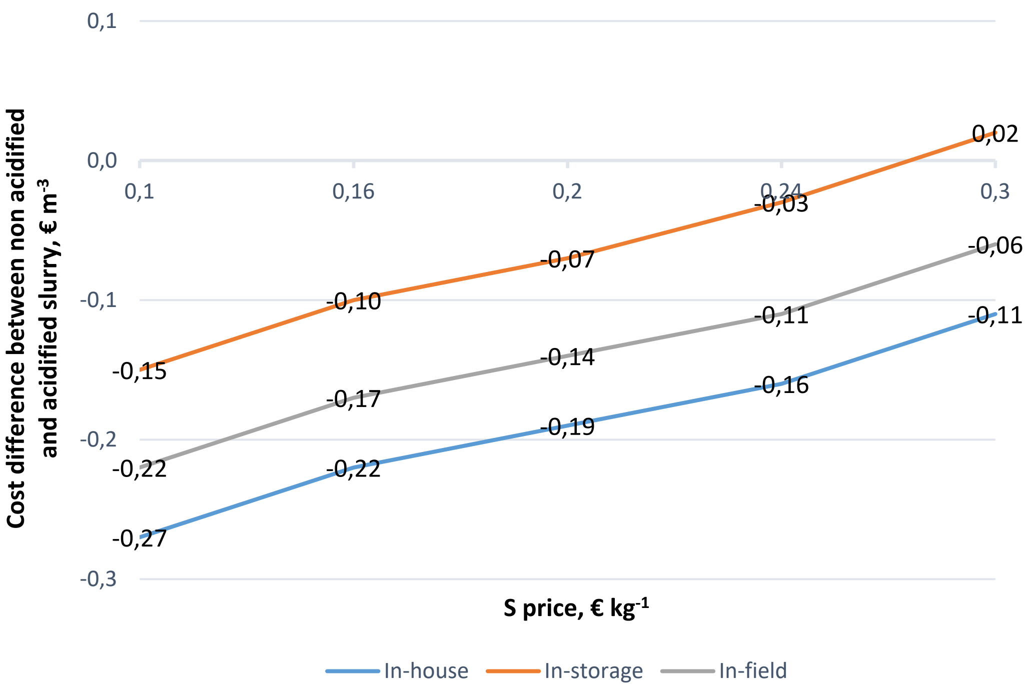

Figure 96. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

Table 119. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.1	1.86	3.63	**1.77**	2.25	2.61	**0.36**	2.38	2.52	**0.14**
0.16	1.80	3.63	**1.83**	2.20	2.61	**0.41**	2.33	2.52	**0.19**
0.2	1.76	3.63	**1.87**	2.17	2.61	**0.44**	2.29	2.52	**0.23**
0.24	1.72	3.63	**1.91**	2.14	2.61	**0.47**	2.26	2.52	**0.26**
0.3	1.65	3.63	**1.98**	2.09	2.61	**0.52**	2.21	2.52	**0.31**

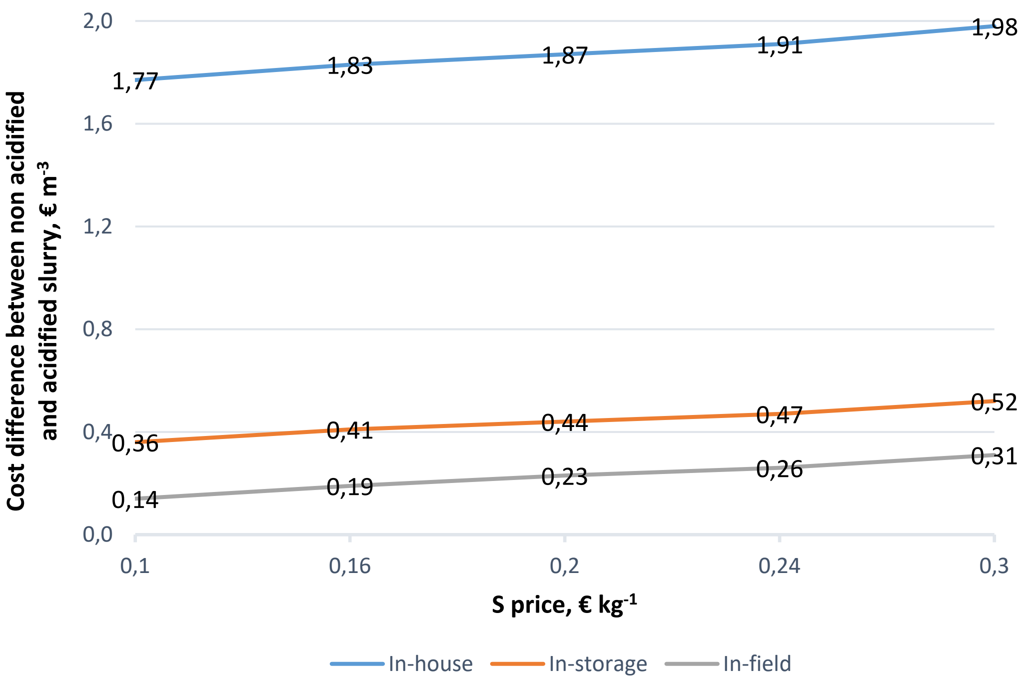

Figure 97. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

5.7.7. Summary, Lithuania

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The calculation results show, that in Lithuania by all cattle slurry amounts, if slurry is acidified, then costs are higher than by non-acidified but incorporated slurry. The reason is mainly very high liming costs - 175 € t^{-1} for liming service including liming material and transport. Another reason is relatively low S price compared to other project countries (0.15 € kg^{-1} and 0.11–0.85 € kg^{-1}). The cost- benefit of cattle slurry acidification would be positive if the acid need would be lower (figure 90), N_{tot} content of slurry higher (figure 92) or mineral N price higher (figure 94).

The minimal pig slurry amounts should be between 3,200–10,800 m^3 yearly depending on SAT (see Table 107).

Acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save
2) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry
3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower)

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) decreases if acid amount per cubicmeter increases. While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The acid price by in-house SAT (128 € m^{-3}) is lower than by other SATs (157 € m^{-3}) and this is the reason why change of acid amount has smaller effect on cost-benefit by first SAT compared to others.

The calculations in paragraph 5.5 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts (Figure 50) show that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1} .

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount reaches the demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount per hectare and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. In-house acidification of cattle slurry has positive cost-benefit only compared to tent cover. In-house acidification of pig slurry has positive cost-benefit compared to all cover types.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises (see 5.7.4). N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises (see 5.7.5). The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises (see 5.7.6).

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analyses with local parameters and future prices should be performed before deciding to invest to acidification system. The analyses model will be available on project website.

5.8.Poland

5.8.1. Annual slurry amount, Poland

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The acid price in the calculations is 128 € t^{-1} for in-house acidification and 157 € t^{-1} for in-storage and in-field acidification. Minimum storage period 6 month. N-fertilisers is AN34, 250 € t^{-1}. NS-fertiliser N21-S24, 230 € t^{-1}. Thus N price 0.73 € kg^{-1} and S price 0.26 € kg^{-1}. The prices of project partner countries are between 0.48–1 and 0.11–0.85€ kg^{-1} respectively.

All three SATs have cost- benefit by cattle and pig slurry both in Poland.

The minimal slurry amounts should be between 2,800–7,900 and 2,100–6,100. m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 120).

Table 120. The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit.

SAT	Dairy cows: Annual slurry amount, m^3	Dairy cows: Number of animal	Fatteners: Annual slurry amount, m^3	Fatteners: Number of animal per year
In-house	7,632	318	5,019	10,037
In-storage	2,808	117	2,066	4,132
In-field	7,872	328	6,135	12,270

Table 121. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1,200	10.33	6.39	**-3.94**	7.58	6.34	**-1.24**	11.44	6.33	**-5.11**
2,400	6.47	5.12	**-1.35**	5.22	5.07	**-0.15**	7.09	5.06	**-2.03**

9,000	3.21	3.36	**0.15**	2.80	3.32	**0.52**	3.21	3.30	**0.09**
12,000	2.73	3.07	**0.34**	2.48	3.02	**0.54**	2.76	3.01	**0.25**
21,000	2.14	2.57	**0.43**	1.99	2.53	**0.54**	2.10	2.52	**0.42**
24,000	2.00	2.47	**0.47**	1.89	2.43	**0.54**	1.97	2.41	**0.44**
33,000	1.77	2.24	**0.47**	1.69	2.19	**0.50**	1.72	2.18	**0.46**
48,000	1.52	1.99	**0.47**	1.49	1.95	**0.46**	1.48	1.93	**0.45**

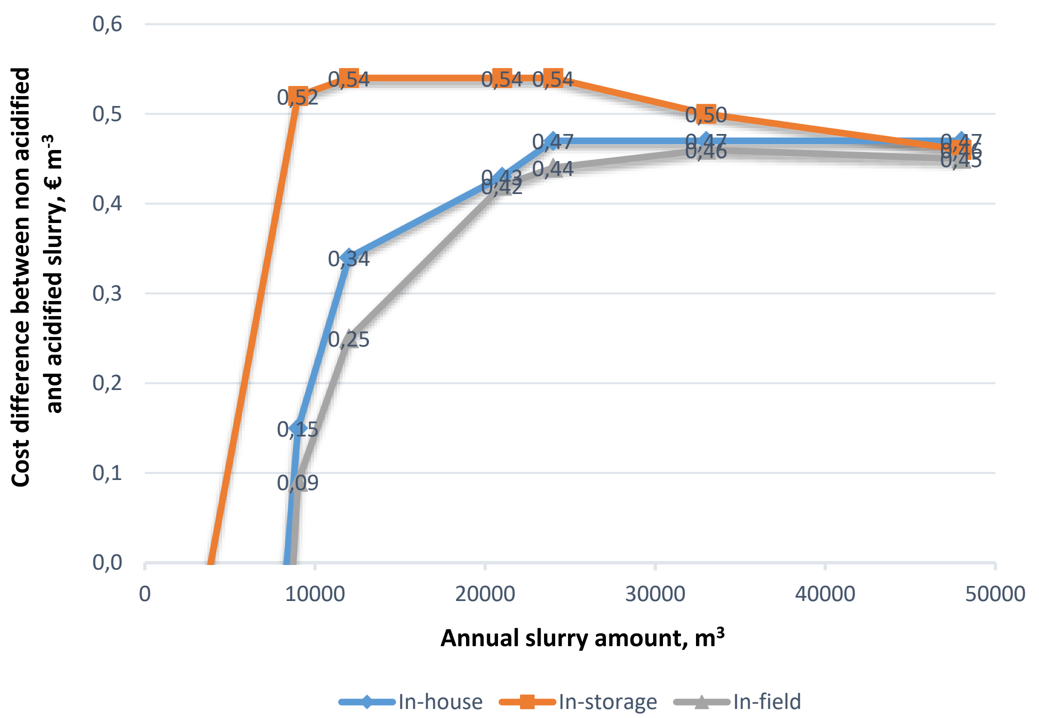

Figure 98. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Table 122. Fattener slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
500	32.65	8.63	**-24.02**	12.43	8.44	**-3.99**	21.97	8.42	**-13.55**
2,500	7.84	5.21	**-2.63**	4.81	5.02	**0.21**	6.68	5.00	**-1.68**
5,000	4.22	4.21	**-0.01**	3.33	4.02	**0.69**	4.25	4.00	**-0.25**
9,000	2.57	3.52	**0.95**	2.49	3.33	**0.84**	2.99	3.31	**0.32**
21,000	1.13	2.73	**1.60**	1.68	2.55	**0.87**	1.88	2.53	**0.65**
33,000	0.66	2.40	**1.74**	1.38	2.21	**0.83**	1.50	2.19	**0.69**

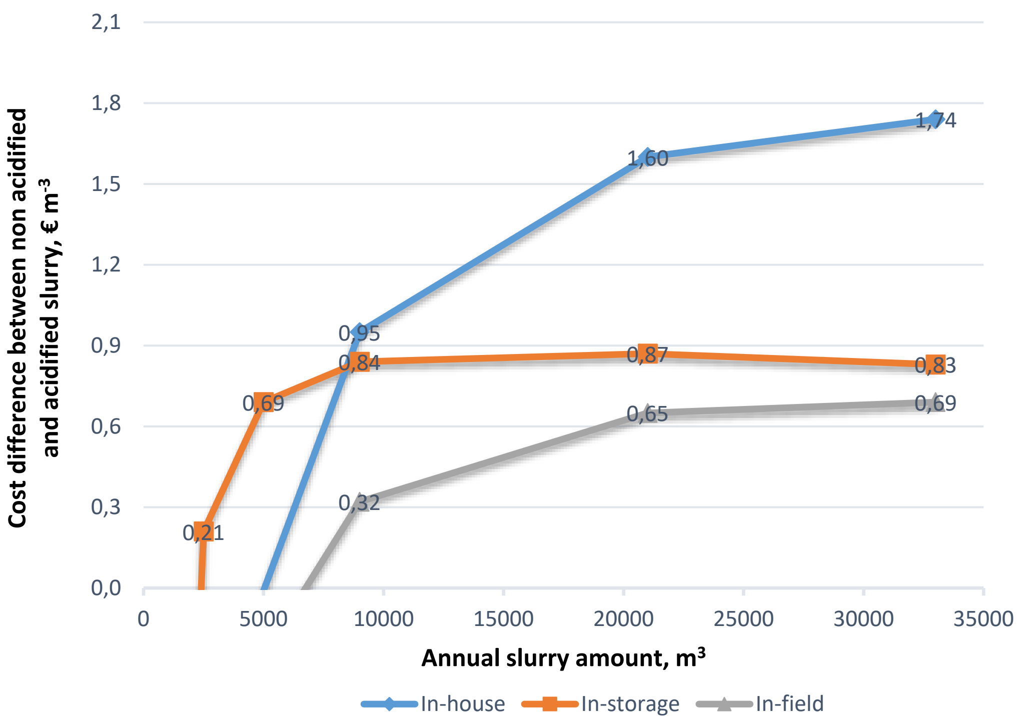

Figure 99. The cost decrease (€ m^{-3}) by use of fattener slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

5.8.2. Cover type, Poland

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 100 and 101 show also that the order of cover types is same for both, cattle and big slurries.

In Poland, the required minimum manure storage capacity is 6 months. In this analysis is presumed that animal are housed in all year around and storage depth is 5 m. The capital cost of slurry storage cover calculated for these conditions are shown in the table 21.

Table 123. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	In-house Acid	No acid	Dif.
No cover	2.14	2.57	**0.43**
Chopped straw	2.33	2.62	**0.29**
Fibo clay balls (fraction 10-20 mm)	2.38	2.64	**0.26**
Floating foil	2.39	2.65	**0.26**
Hexa-cover plates	2.41	2.66	**0.25**
Peat	2.39	2.87	**0.48**
Rapeseed oil	2.38	3.30	**0.92**
Tent cover	2.42	2.93	**0.51**

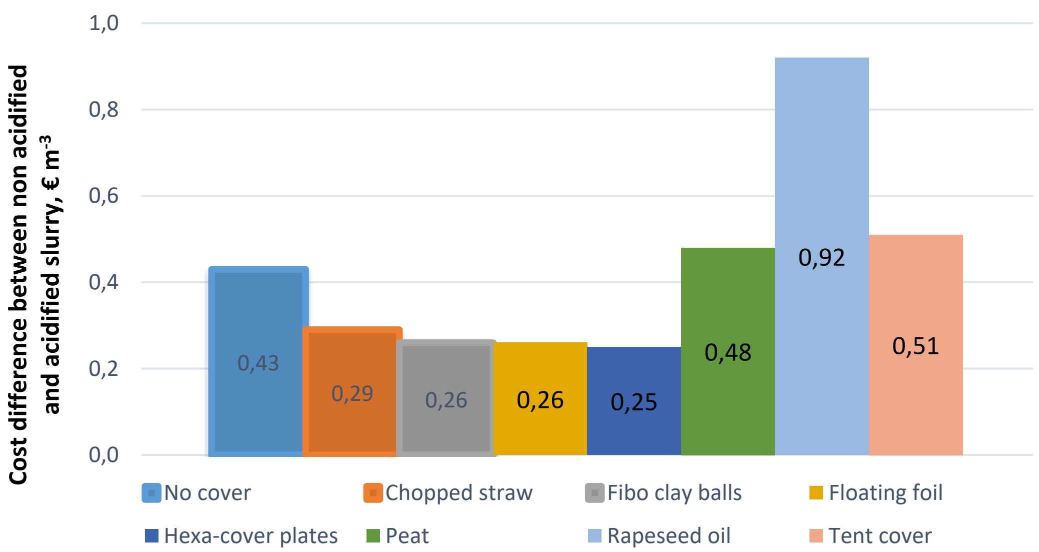

Figure 100. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Table 124. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	In-house Acid	No acid	Dif.
No cover	1.13	2.73	**1.60**
Chopped straw	1.37	2.77	**1.40**
Fibo clay balls (fraction 10-20 mm)	1.43	2.79	**1.36**
Floating foil	1.44	2.80	**1.36**
Hexa-cover plates	1.46	2.81	**1.35**

Peat	1.44	3.02	**1.58**
Rapeseed oil	1.43	3.44	**2.01**
Tent cover	1.48	3.07	**1.59**

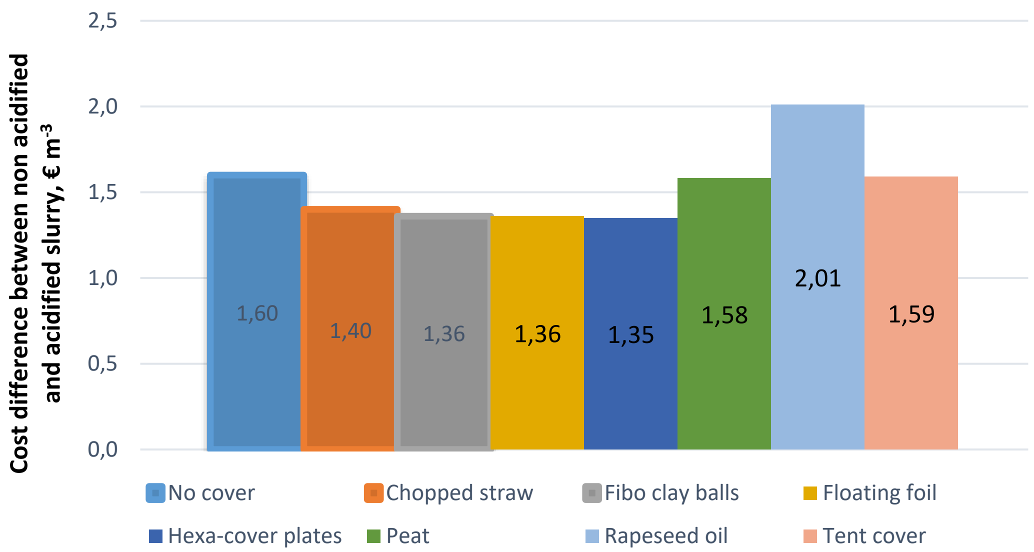

Figure 101. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners.

5.8.3. Acid consumption, Poland

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) decreases if acid amount per cubicmeter increases.

If acid consumption ↑ 1 l m^{-3}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↓0.28 € m^{-3}	↓0.27 € m^{-3}
in-storage SAT:	↓0.34 € m^{-3}	↓0.34 € m^{-3}
in-field SAT:	↓0.35 € m^{-3}	↓0.35 € m^{-3}

Acid content change in slurry has lowest impact by in-house SAT and biggest by in-field SAT. The reason is that the acid price for in-house SAT is lower (128 € t^{-1}) than by other SATs (157 € t^{-1}).

Table 125. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	1.21	2.57	**1.36**	1.17	2.53	**1.36**	1.47	2.52	**1.05**
3	1.70	2.57	**0.87**	1.77	2.53	**0.76**	2.10	2.52	**0.42**
4	1.99	2.57	**0.58**	2.13	2.53	**0.40**	2.46	2.52	**0.06**
5	2.29	2.57	**0.28**	2.48	2.53	**0.05**	2.83	2.52	**-0.31**
7	2.88	2.57	**-0.31**	3.19	2.53	**-0.66**	3.56	2.52	**-1.04**

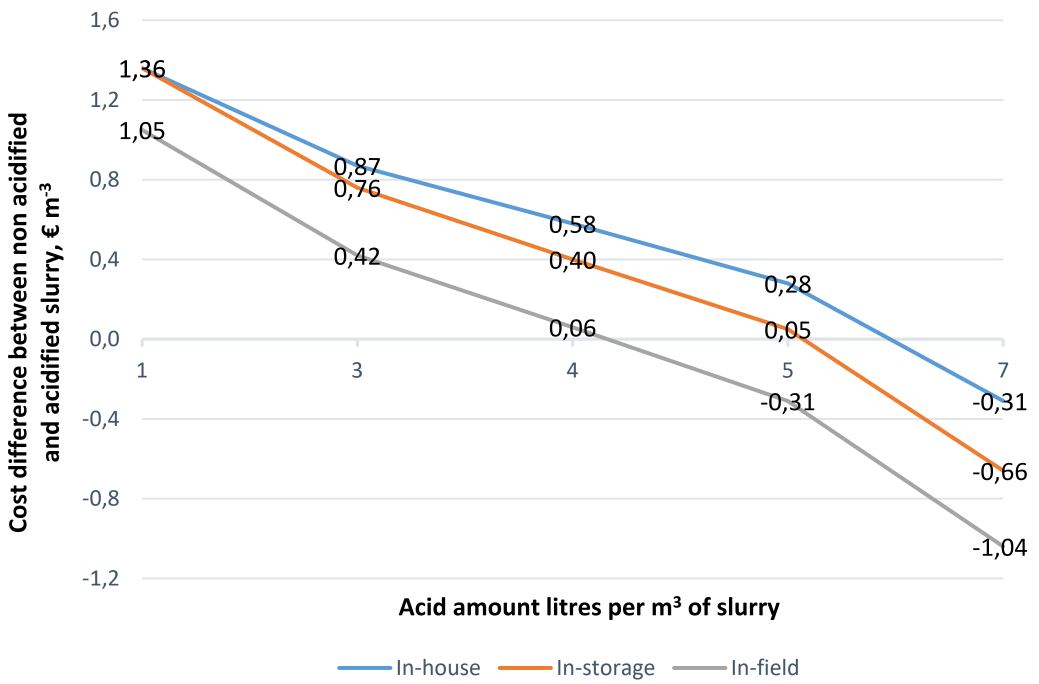

Figure 102. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

Table 126. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	0.57	2.73	**2.16**	1.07	2.55	**1.48**	1.39	2.53	**1.14**
3	0.98	2.73	**1.75**	1.68	2.55	**0.87**	2.02	2.53	**0.51**
4	1.28	2.73	**1.45**	2.04	2.55	**0.51**	2.39	2.53	**0.14**
5	1.57	2.73	**1.16**	2.39	2.55	**0.16**	2.75	2.53	**-0.22**
7	2.16	2.73	**0.57**	3.10	2.55	**-0.55**	3.49	2.53	**-0.96**

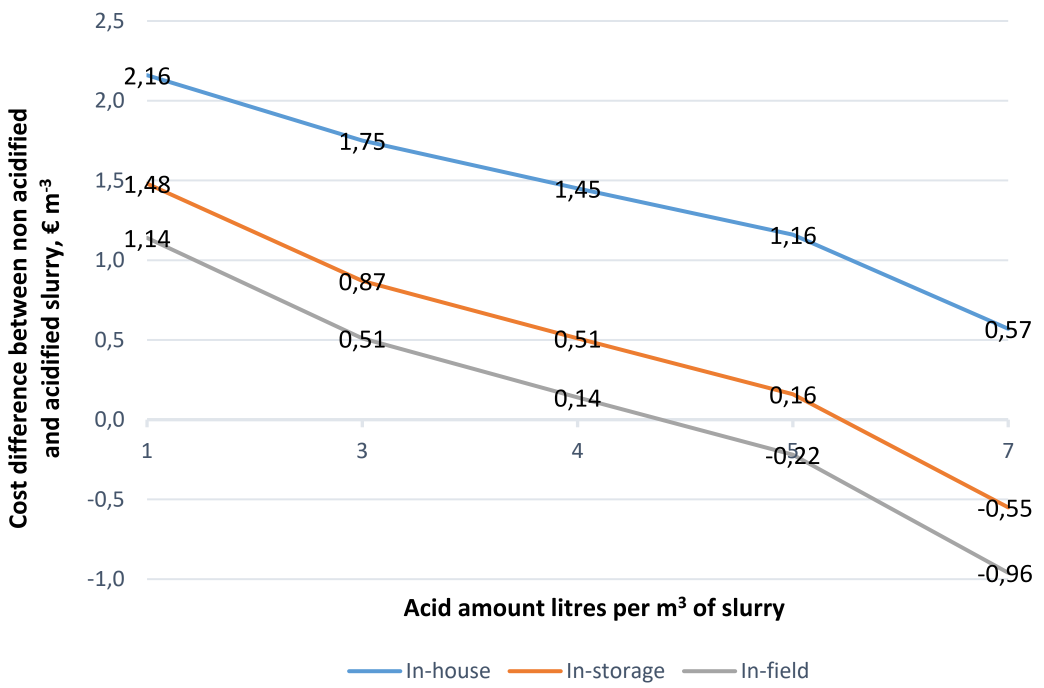

Figure 103. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

5.8.4. N_{tot} in slurry, Poland

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

If N_{tot} content in slurry ↑ 1 kg m^{-3} , then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.14 € m^{-3}.	↑0.27 € m^{-3}.
in-storage SAT:	↑0.11 € m^{-3}.	↑0.11 € m^{-3}.
in-field SAT:	↑0.08 € m^{-3}	↑0.09 € m^{-3}.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.

Table 127. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
3				2.13	2.51	**0.38**	2.21	2.50	**0.29**
4	2.36	2.54	**0.18**	2.03	2.52	**0.49**	2.13	2.51	**0.38**

5	2.25	2.56	**0.31**	1.94	2.54	**0.60**	2.06	2.52	**0.46**
6	2.13	2.58	**0.45**	1.85	2.55	**0.70**	1.99	2.53	**0.54**
7	2.01	2.60	**0.59**						

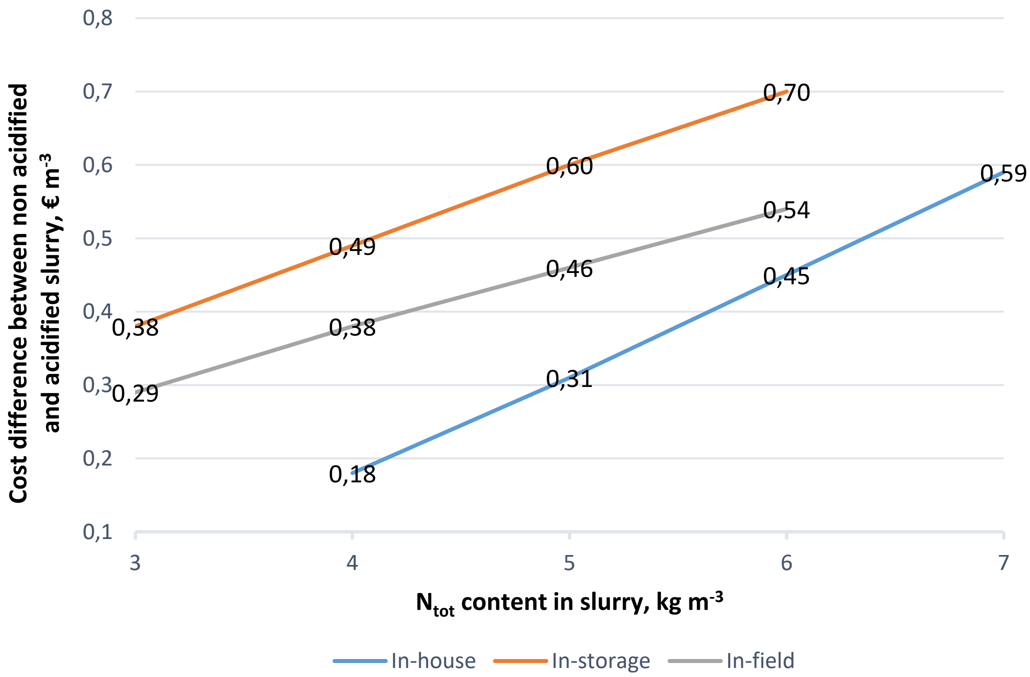

Figure 104. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Table 128. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
4				1.82	2.52	**0.70**	1.99	2.51	**0.52**
5	1.60	2.66	**1.06**	1.73	2.54	**0.81**	1.91	2.52	**0.61**
6	1.36	2.69	**1.33**	1.64	2.55	**0.91**	1.84	2.53	**0.69**
7	1.13	2.73	**1.60**	1.54	2.57	**1.03**	1.77	2.55	**0.78**
8	0.89	2.77	**1.88**						

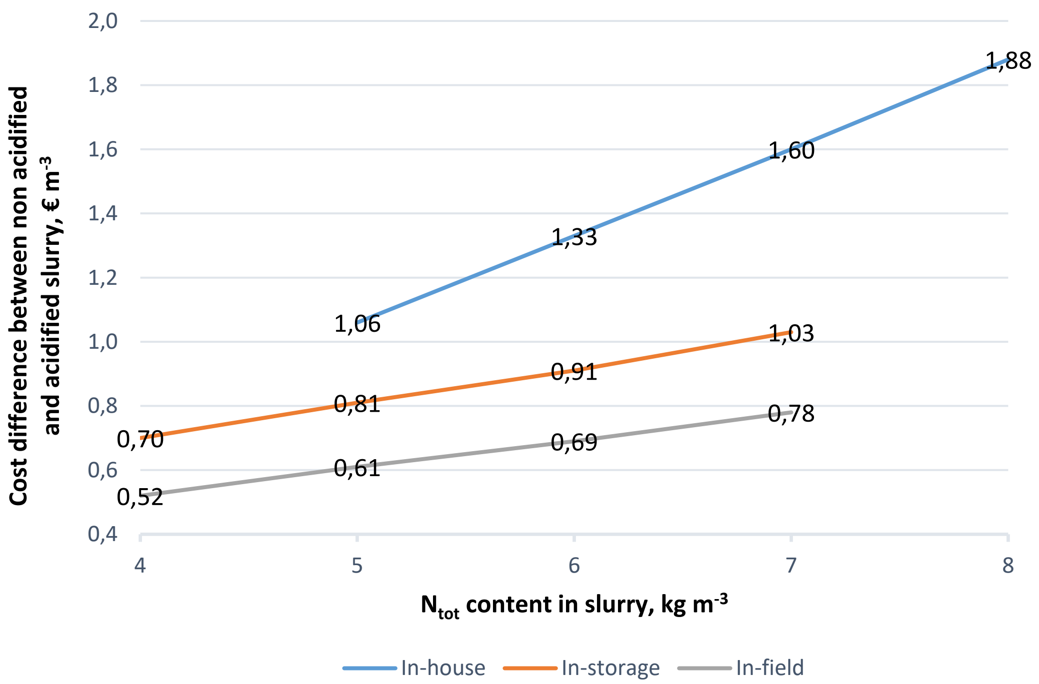

Figure 105. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

5.8.5. N price, Poland

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises.

N price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.089 € m^{-3}.	↑0.21 € m^{-3}.
in-storage SAT:	↑0.054 € m^{-3}.	↑0.07 € m^{-3}.
in-field SAT:	↑0.043 € m^{-3}	↑0.05 € m^{-3}.

The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.
Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

Table 129. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.37	2.47	2.57	**0.10**	2.19	2.53	**0.34**	2.26	2.52	**0.26**

0.592	2.27	2.57	**0.30**	2.07	2.53	**0.46**	2.16	2.52	**0.36**
0.74	2.14	2.57	**0.43**	1.99	2.53	**0.54**	2.10	2.52	**0.42**
0.888	2.01	2.57	**0.56**	1.91	2.53	**0.62**	2.04	2.52	**0.48**
1.11	1.81	2.57	**0.76**	1.79	2.53	**0.74**	1.94	2.52	**0.58**

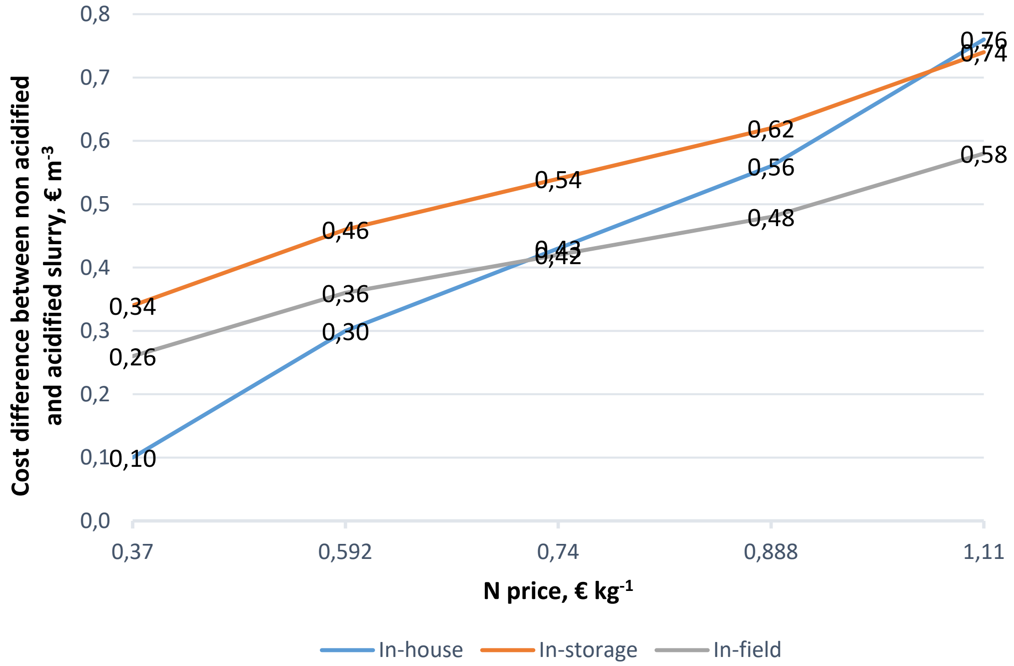

Figure 106. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

Table 130. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.37	1.91	2.73	**0.82**	1.93	2.55	**0.62**	2.07	2.53	**0.46**
0.592	1.44	2.73	**1.29**	1.78	2.55	**0.77**	1.96	2.53	**0.57**
0.74	1.12	2.73	**1.61**	1.68	2.55	**0.87**	1.88	2.53	**0.65**
0.888	0.81	2.73	**1.92**	1.59	2.55	**0.96**	1.80	2.53	**0.73**
1.11	0.34	2.73	**2.39**	1.44	2.55	**1.11**	1.68	2.53	**0.85**

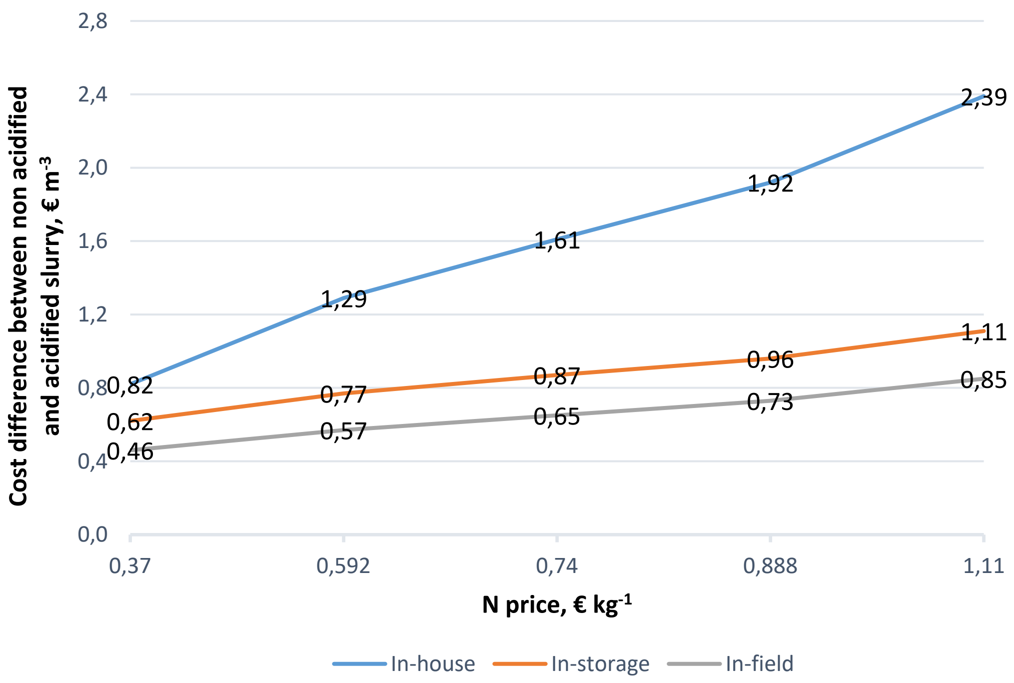

Figure 107. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

5.8.6. S price, Poland

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

S price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-pit SAT:	↑0.08 € m^{-3}.	↑0.11 € m^{-3}.
in-storage SAT:	↑0.08 € m^{-3}.	↑0.08 € m^{-3}.
in-field SAT:	↑0.08 € m^{-3}	↑0.08 € m^{-3}.

Table 131. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.155	2.27	2.57	**0.30**	2.12	2.53	**0.41**	2.23	2.52	**0.29**
0.248	2.19	2.57	**0.38**	2.04	2.53	**0.49**	2.15	2.52	**0.37**
0.31	2.14	2.57	**0.43**	1.99	2.53	**0.54**	2.10	2.52	**0.42**
0.372	2.09	2.57	**0.48**	1.94	2.53	**0.59**	2.05	2.52	**0.47**
0.465	2.01	2.57	**0.56**	1.86	2.53	**0.67**	1.97	2.52	**0.55**

Figure 108. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

Table 132. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.155	1.29	2.73	**1.44**	1.81	2.55	**0.74**	2.01	2.53	**0.52**
0.248	1.19	2.73	**1.54**	1.73	2.55	**0.82**	1.93	2.53	**0.60**
0.31	1.12	2.73	**1.61**	1.68	2.55	**0.87**	1.88	2.53	**0.65**
0.372	1.06	2.73	**1.67**	1.63	2.55	**0.92**	1.83	2.53	**0.70**
0.465	0.96	2.73	**1.77**	1.55	2.55	**1.00**	1.75	2.53	**0.78**

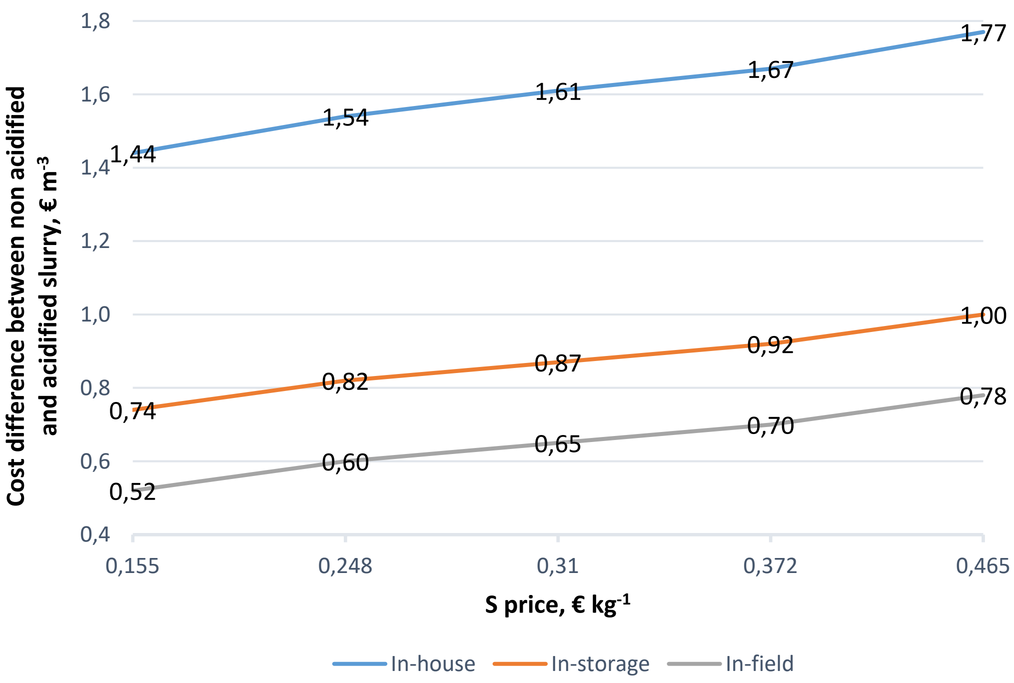

Figure 109. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

5.8.7. Summary, Poland

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry.

All threes SATs have cost- benefit by cattle and pig slurry both in Poland.

The minimal slurry amounts should be between 2,800–7,900 1 and 2,100–6,100 m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 120).

Acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save
2) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry
3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower)

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) decreases if acid amount per cubicmeter increases. While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The acid price by in-house SAT (128 € m^{-3}) is lower than by other SATs (157 € m^{-3}) and this is the reason why change of acid amount has smaller effect on cost-benefit by first SAT compared to others.

The calculations in paragraph 5.5 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts (Figure 50) show that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1} .

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount reaches the demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount per hectare and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost benefit. The figures 100 and 101 show also that the order of cover types is same for both, cattle and big slurries.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises (see 5.8.4). N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises (see 5.8.5). The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises (see 5.8.6). The change of S price in mineral fertilisers has same impact by different SATs and slurry types, except bigger difference by pig slurry with in-house SAT.

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system. The analysis model will be available on project website

5.9. Russia

5.9.1. Annual slurry amount, Russia

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The acid price in the calculations is 142 € t^{-1} for in-house acidification and 112 € t^{-1} for in-storage and in-field acidification. The acid transport in IBC tanks is in Russia cheaper than in big tanks. Minimum storage period for cattle manure is 6 month and for pig manure 12 month. N-fertilisers is N 100%, 523 € t^{-1}. NS-fertiliser N30-S6, 170 € t^{-1}. Thus N price 0.52 € kg^{-1} and S price 0.15 € kg^{-1}. The prices of project partner countries are between 0.48–1 and 0.11–0.85 € kg^{-1} respectively.

The calculation results show, that in Russia by all cattle slurry amounts, if slurry is acidified by in-house or in-field SAT, then costs are higher to non-acidified but incorporated slurry costs. The cost-benefit of in-storage acidification of cattle slurry is zero if slurry mount is 17,800 m^3 yealy. The reason of low cost-benefit is small slurry incorporation cost - 14 € ha^{-1}. Another reason is relatively low N and S price.

The minimal pig slurry amounts should be between 5,000–17,900 m^3 yearly depending on SAT (see Table 133).

Table 133. The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit.

SAT	Dairy cows		Fatteners	
	Annual slurry amount, m^3	Number of animal	Annual slurry amount, m^3	Number of animal per year
In-house	NA	NA	12,938	25,876
In-storage	17,839	743	5,011	10,021
In-field	NA	NA	17,935	35,869

Table 134. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1,200	11.15	5.83	**-5.32**	7.68	5.74	**-1.94**	11.88	5.72	**-6.16**
2,400	7.01	4.41	**-2.60**	5.12	4.32	**-0.80**	7.16	4.30	**-2.86**
9,000	3.63	2.62	**-1.01**	2.60	2.53	**-0.07**	3.06	2.51	**-0.55**
12,000	3.14	2.34	**-0.80**	2.29	2.26	**-0.03**	2.60	2.23	**-0.37**
21,000	2.55	1.90	**-0.65**	1.81	1.81	**0.00**	1.95	1.79	**-0.16**
24,000	2.41	1.80	**-0.61**	1.72	1.72	**0.00**	1.82	1.69	**-0.13**
33,000	2.19	1.60	**-0.59**	1.53	1.52	**-0.01**	1.58	1.49	**-0.09**
48,000	1.95	1.40	**-0.55**	1.35	1.32	**-0.03**	1.35	1.29	**-0.06**

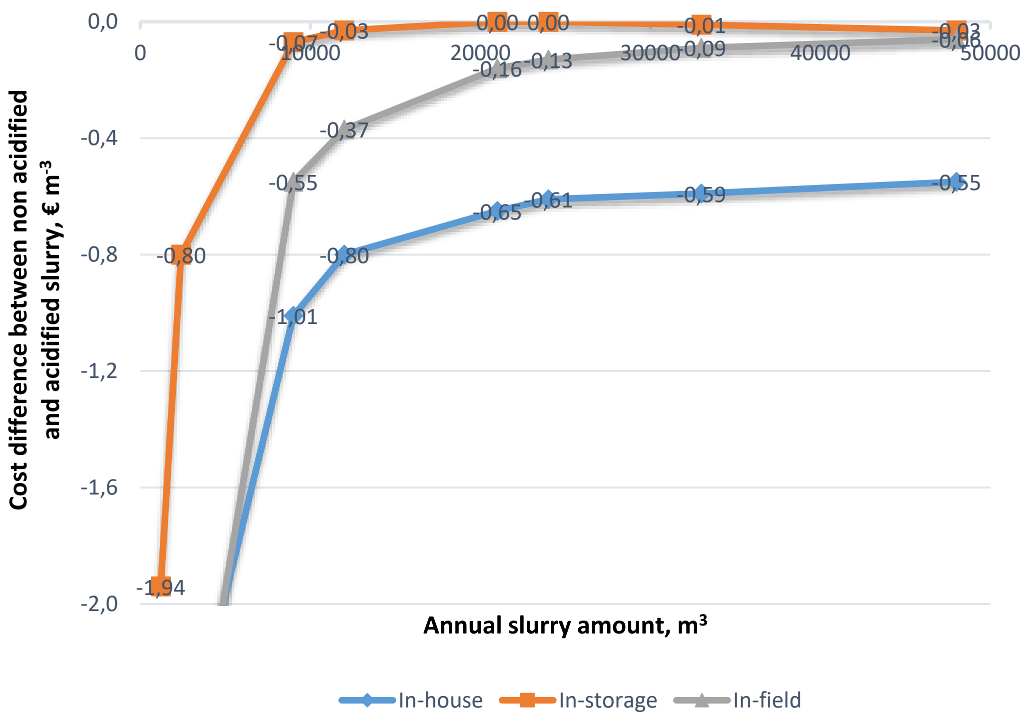

Figure 110. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Table 135. Fattener slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-house			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
500	36.16	8.63	**-27.53**	13.21	8.28	**-4.93**	23.50	8.24	**-15.26**
2,500	8.94	4.63	**-4.31**	4.79	4.28	**-0.51**	6.78	4.25	**-2.53**
5,000	5.04	3.59	**-1.45**	3.24	3.24	**0.00**	4.20	3.21	**-0.99**
9,000	3.30	2.91	**-0.39**	2.38	2.56	**0.18**	2.88	2.53	**-0.35**
21,000	1.81	2.19	**0.38**	1.58	1.84	**0.26**	1.77	1.81	**0.04**
33,000	1.34	1.90	**0.56**	1.29	1.55	**0.26**	1.40	1.52	**0.12**

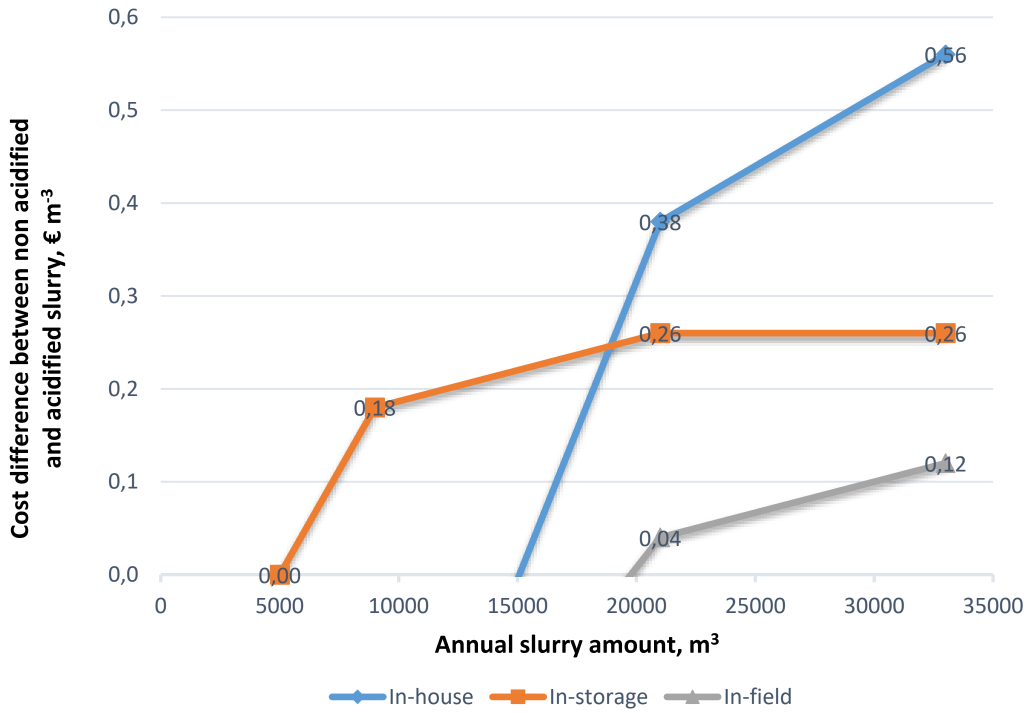

Figure 111. The cost decrease (€ m^{-3}) by use of fattener slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

5.9.2. Cover type, Russia

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. In-house acidification of cattle slurry has no positive cost-benefit by any type of artificial coverer. In-house acidification of pig slurry has positive cost-benefit compared to all cover types. Biggest cost-effect of in-house acidification of pig slurry is compared to rapseed oil, which is followed by tent and peat (Figure 113).

In Russia, minimum storage period for cattle manure is 6 month and for pig manure 12 month.. In this analysis is presumed that animal are housed in all year around and storage depth is 5 m. The capital cost of slurry storage cover calculated for these conditions are shown in the table 21.

Table 136. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	Acid	In-house No acid	**Dif.**
No cover	2.55	1.90	**-0.65**
Chopped straw	2.68	1.92	**-0.76**
Fibo clay balls (fraction 10-20 mm)	2.71	1.93	**-0.78**
Floating foil	2.72	1.94	**-0.78**
Hexa-cover plates	2.73	1.95	**-0.78**
Peat	2.72	2.16	**-0.56**
Rapeseed oil	2.71	2.58	**-0.13**
Tent cover	2.74	2.21	**-0.53**

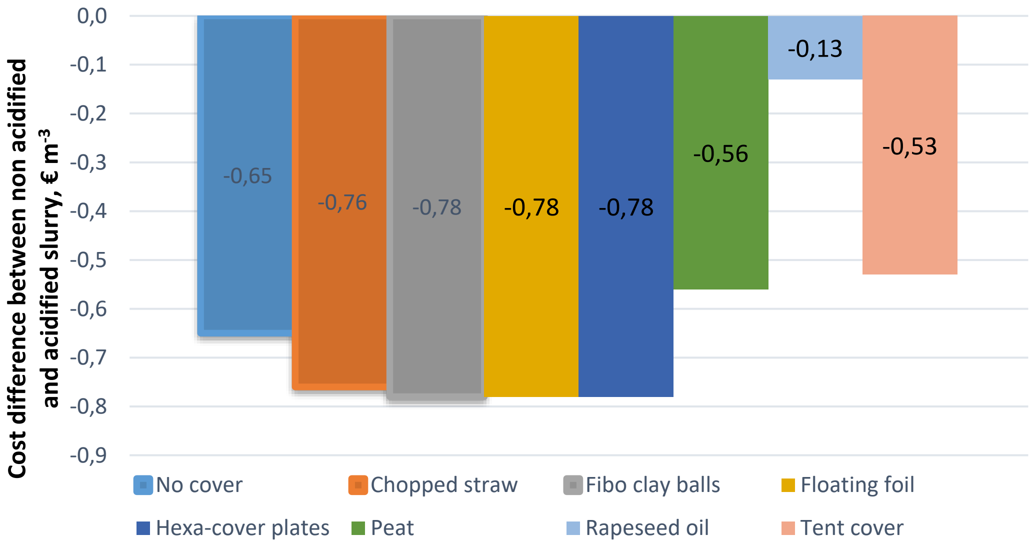

Figure 112. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Table 137. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	Acid	In-house No acid	**Dif.**
No cover	1.81	2.19	**0.38**
Chopped straw	1.98	2.28	**0.30**
Fibo clay balls (fraction 10-20 mm)	2.02	2.32	**0.30**
Floating foil	2.03	2.34	**0.31**
Hexa-cover plates	2.04	2.35	**0.31**
Peat	2.03	2.78	**0.75**

Rapeseed oil	2.02	3.62	**1.60**
Tent cover	2.05	2.88	**0.83**

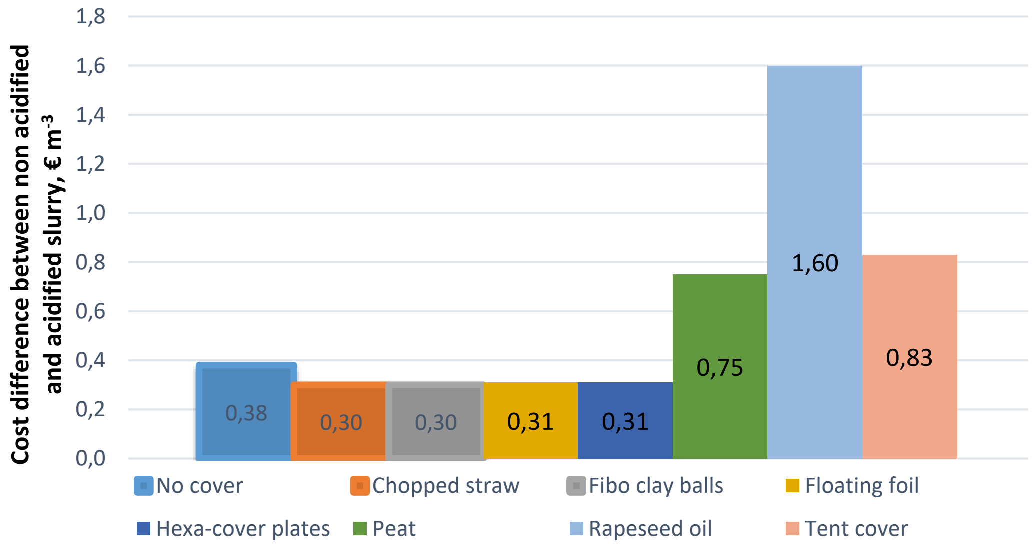

Figure 113. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners.

5.9.3. Acid consumption, Russia

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) decreases if acid amount per cubicmeter increases.

If acid consumption ↑ 1 l m^{-3}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↓0.35 € m^{-3}	↓0.34 € m^{-3}
in-storage SAT:	↓0.29 € m^{-3}	↓0.29 € m^{-3}
in-field SAT:	↓0.31 € m^{-3}	↓0.31 € m^{-3}

Acid content change in slurry has similar impact by all SATs. The reason is that the acid price for in-house SAT is lower (128 € t^{-1}) than by other SATs (157 € t^{-1}).

Table 138. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount	In-house			In-storage			In-field		
l m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**

1	1.35	1.90	**0.55**	1.09	1.81	**0.72**	1.38	1.79	**0.41**
3	2.00	1.90	**-0.10**	1.63	1.81	**0.18**	1.95	1.79	**-0.16**
4	2.37	1.90	**-0.47**	1.93	1.81	**-0.12**	2.26	1.79	**-0.47**
5	2.73	1.90	**-0.83**	2.24	1.81	**-0.43**	2.58	1.79	**-0.79**
7	3.45	1.90	**-1.55**	2.85	1.81	**-1.04**	3.21	1.79	**-1.42**

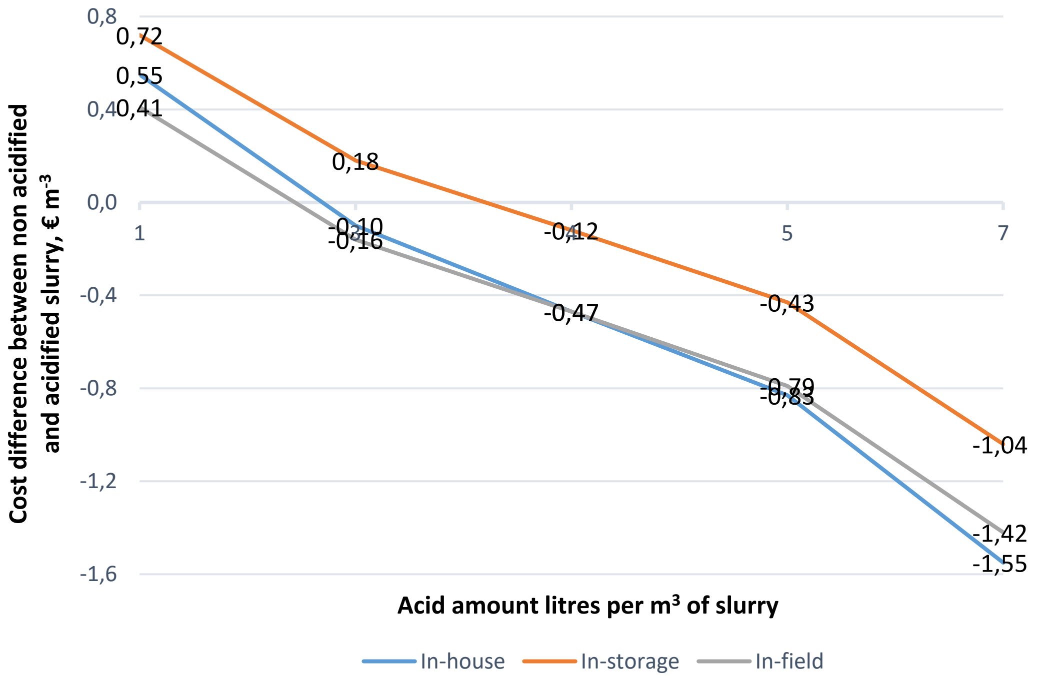

Figure 114. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

Table 139. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount l m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	1.03	2.19	**1.16**	1.04	1.84	**0.80**	1.33	1.81	**0.48**
3	1.63	2.19	**0.56**	1.58	1.84	**0.26**	1.89	1.81	**-0.08**
4	1.99	2.19	**0.20**	1.88	1.84	**-0.04**	2.21	1.81	**-0.40**
5	2.35	2.19	**-0.16**	2.19	1.84	**-0.35**	2.53	1.81	**-0.72**
7	3.08	2.19	**-0.89**	2.80	1.84	**-0.96**	3.16	1.81	**-1.35**

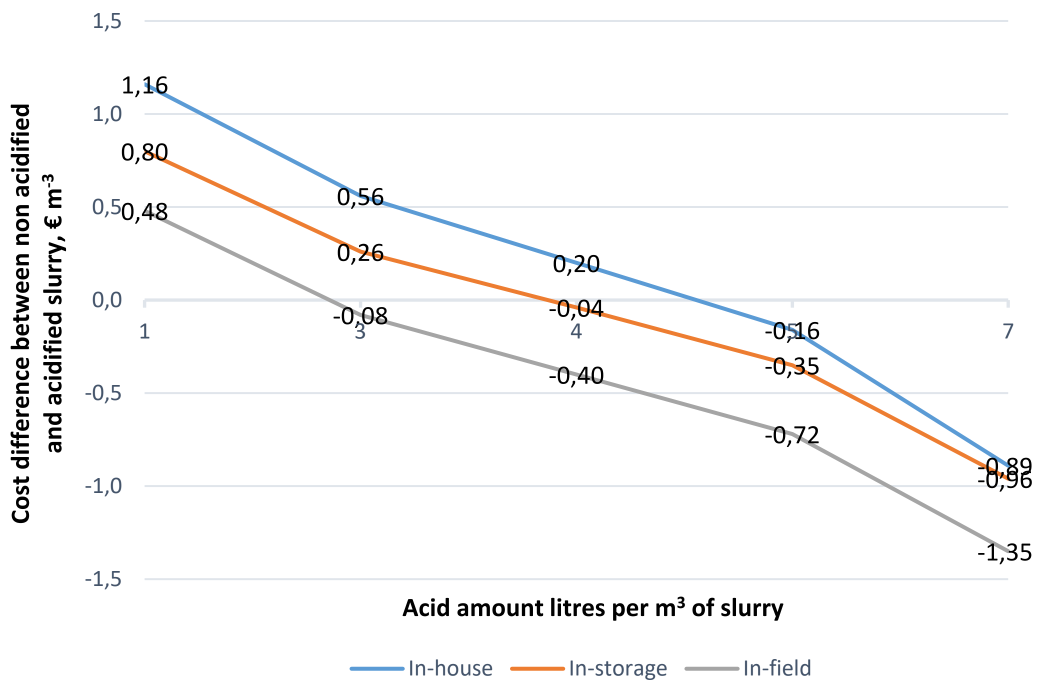

Figure 115. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

5.9.4. N_{tot} in slurry, Russia

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

If N_{tot} content in slurry ↑ 1 kg m^{-3} , then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.12 € m^{-3}.	↑0.24 € m^{-3}.
in-storage SAT:	↑0.10 € m^{-3}.	↑0.09 € m^{-3}.
in-field SAT:	↑0.07 € m^{-3}	↑0.07 € m^{-3}.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house or in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.

Table 140. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content	In-house			In-storage			In-field		
kg m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
3				1.91	1.77	**-0.14**	2.02	1.75	**-0.27**
4	2.70	1.83	**-0.87**	1.84	1.80	**-0.04**	1.97	1.78	**-0.19**

5	2.62	1.86	**-0.76**	1.78	1.83	**0.05**	1.92	1.80	**-0.12**
6	2.54	1.90	**-0.64**	1.71	1.86	**0.15**	1.87	1.82	**-0.05**
7	2.46	1.93	**-0.53**						

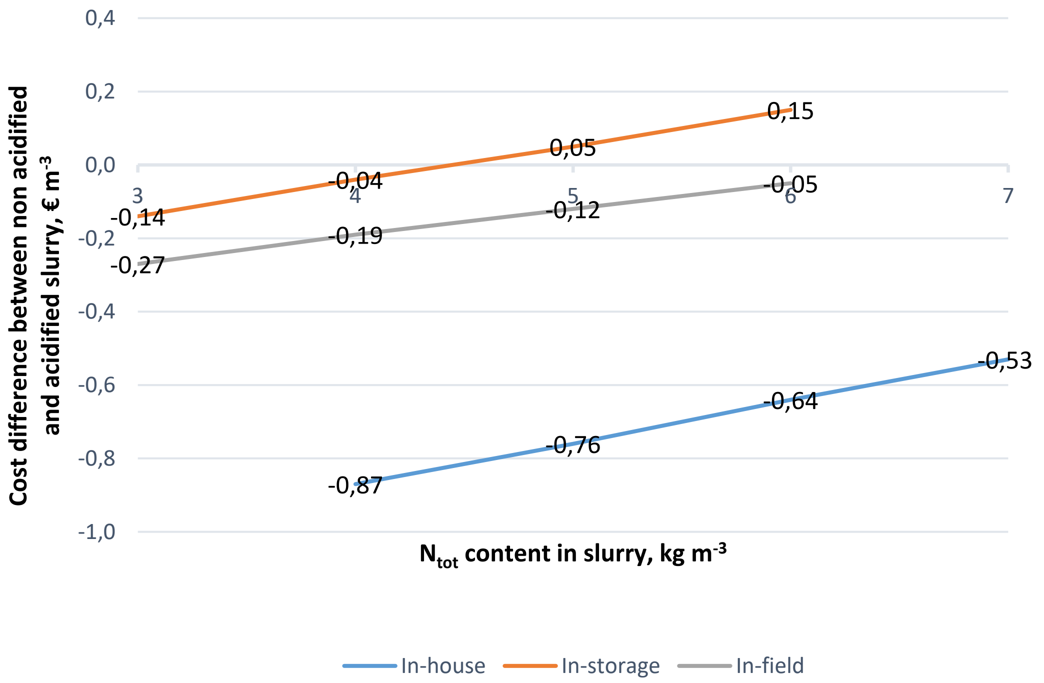

Figure 116. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Table 141. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
4				1.68	1.80	**0.12**	1.84	1.78	**-0.06**
5	2.14	2.05	**-0.09**	1.61	1.83	**0.22**	1.79	1.80	**0.01**
6	1.97	2.12	**0.15**	1.55	1.86	**0.31**	1.74	1.82	**0.08**
7	1.81	2.19	**0.38**	1.48	1.88	**0.40**	1.69	1.84	**0.15**
8	1.64	2.27	**0.63**						

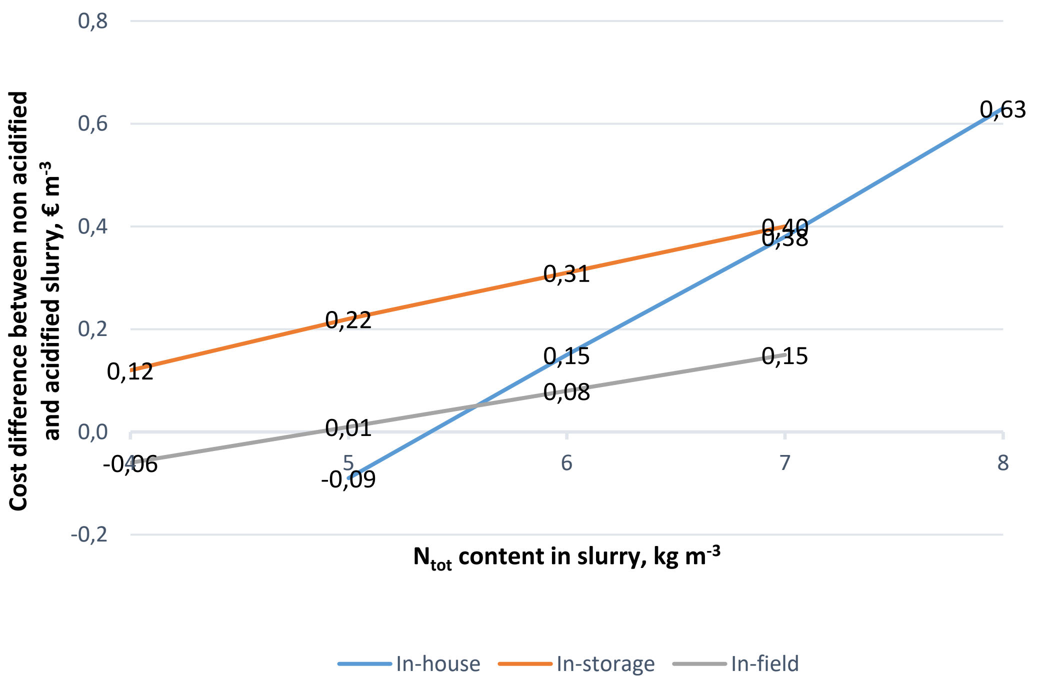

Figure 117. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

5.9.5. N price, Russia

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises.

N price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.088 € m^{-3}.	↑0.21 € m^{-3}.
in-storage SAT:	↑0.054 € m^{-3}.	↑0.07 € m^{-3}.
in-field SAT:	↑0.044 € m^{-3}	↑0.05 € m^{-3}.

The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%.
Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

Table 142. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.26	2.78	1.90	**-0.88**	1.95	1.81	**-0.14**	2.06	1.79	**-0.27**

0.416	2.64	1.90	**-0.74**	1.87	1.81	**-0.06**	1.99	1.79	**-0.20**
0.52	2.55	1.90	**-0.65**	1.81	1.81	**0.00**	1.95	1.79	**-0.16**
0.624	2.46	1.90	**-0.56**	1.75	1.81	**0.06**	1.90	1.79	**-0.11**
0.78	2.32	1.90	**-0.42**	1.67	1.81	**0.14**	1.83	1.79	**-0.04**

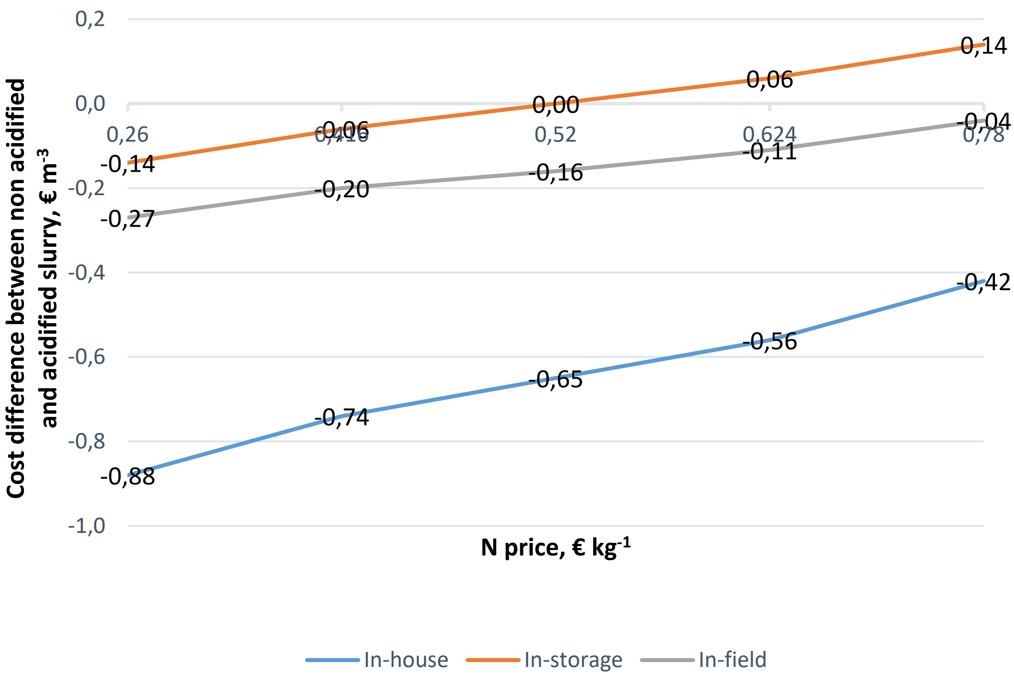

Figure 118. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

Table 143. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.26	2.37	2.19	**-0.18**	1.75	1.84	**0.09**	1.90	1.81	**-0.09**
0.416	2.03	2.19	**0.16**	1.65	1.84	**0.19**	1.82	1.81	**-0.01**
0.52	1.81	2.19	**0.38**	1.58	1.84	**0.26**	1.77	1.81	**0.04**
0.624	1.59	2.19	**0.60**	1.51	1.84	**0.33**	1.71	1.81	**0.10**
0.78	1.26	2.19	**0.93**	1.41	1.84	**0.43**	1.63	1.81	**0.18**

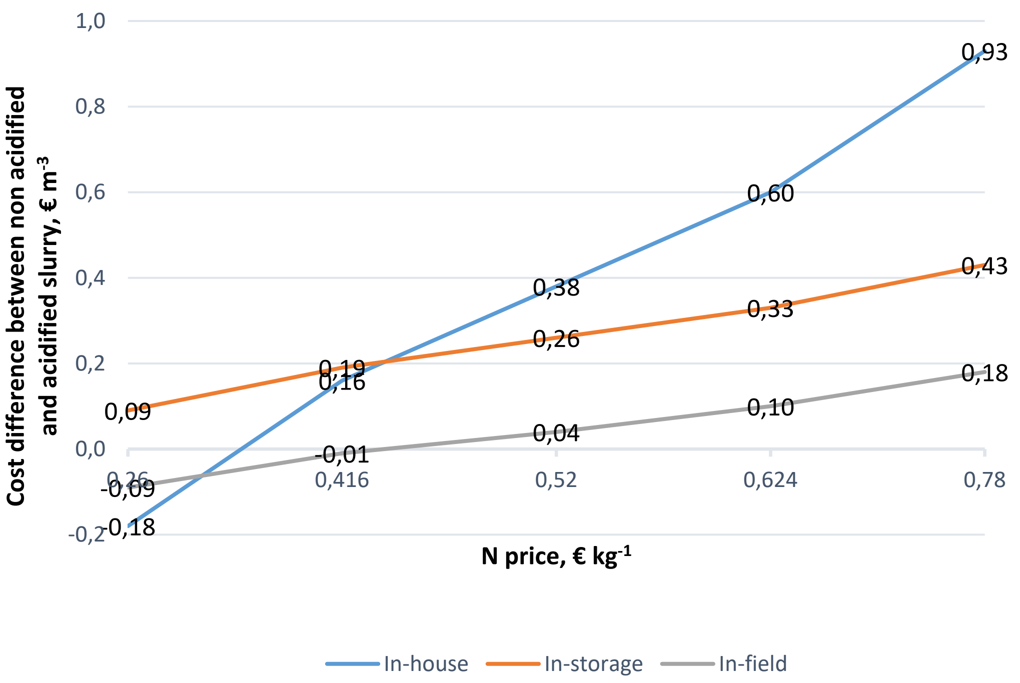

Figure 119. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

5.9.6. S price, Russia

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

S price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-house SAT:	↑0.08 € m^{-3}.	↑0.10 € m^{-3}.
in-storage SAT:	↑0.08 € m^{-3}.	↑0.08 € m^{-3}.
in-field SAT:	↑0.09 € m^{-3}	↑0.08 € m^{-3}.

Table 144. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.11	2.64	1.90	**-0.74**	1.90	1.81	**-0.09**	2.04	1.79	**-0.25**
0.176	2.59	1.90	**-0.69**	1.85	1.81	**-0.04**	1.98	1.79	**-0.19**
0.22	2.55	1.90	**-0.65**	1.81	1.81	**0.00**	1.95	1.79	**-0.16**
0.264	2.51	1.90	**-0.61**	1.77	1.81	**0.04**	1.91	1.79	**-0.12**
0.33	2.46	1.90	**-0.56**	1.72	1.81	**0.09**	1.85	1.79	**-0.06**

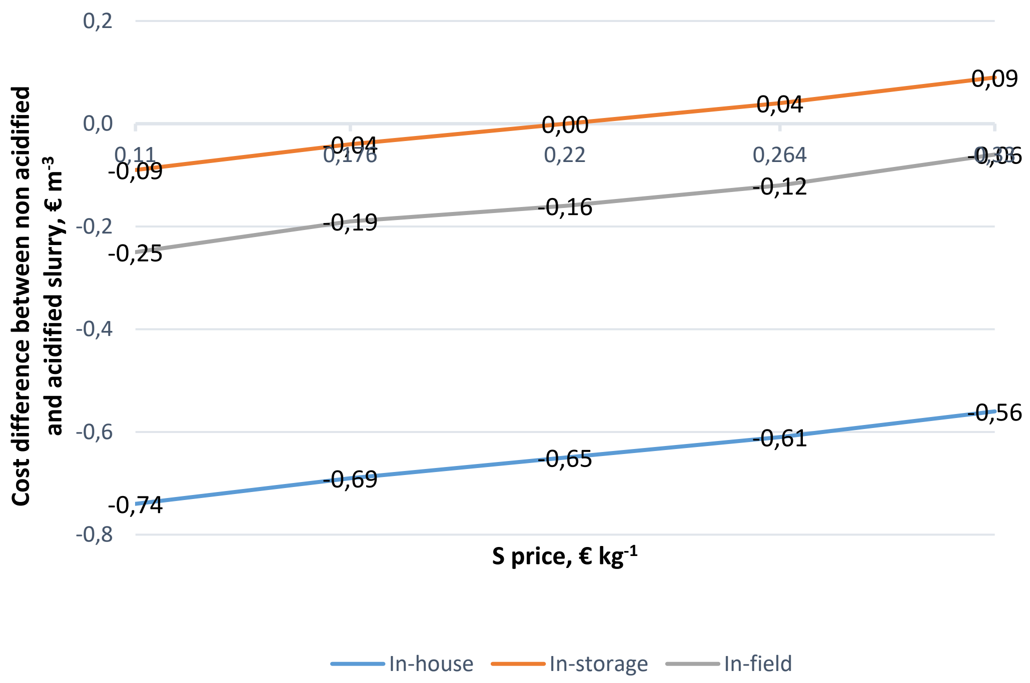

Figure 120. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

Table 145. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-house			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.11	1.93	2.19	**0.26**	1.67	1.84	**0.17**	1.86	1.81	**-0.05**
0.176	1.86	2.19	**0.33**	1.62	1.84	**0.22**	1.80	1.81	**0.01**
0.22	1.81	2.19	**0.38**	1.58	1.84	**0.26**	1.77	1.81	**0.04**
0.264	1.77	2.19	**0.42**	1.54	1.84	**0.30**	1.73	1.81	**0.08**
0.33	1.70	2.19	**0.49**	1.49	1.84	**0.35**	1.68	1.81	**0.13**

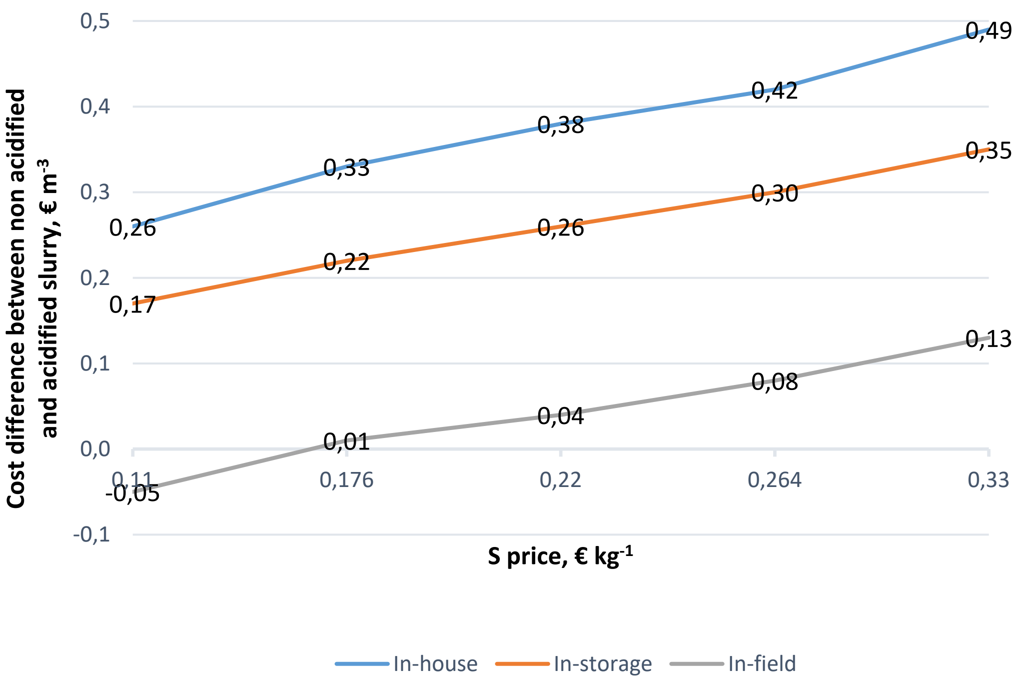

Figure 121. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

5.9.7. Summary, Russia

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The calculation results show, that in Russia by all cattle slurry amounts, if slurry is acidified by in-house or in-field SAT, then costs are higher to non-acidified but incorporated slurry costs. The cost-benefit of in-storage acidification of cattle slurry is zero if slurry mount is 17,800 m^3 yealy. One reason of low cost-benefit is small slurry incorporation cost - 14 € ha^{-1}. Another reason is relatively low N (0.52 compared to 0.48–1 € kg^{-1}) and S price (0.15 compared to 0.11–0.85 € kg^{-1}).

The minimal pig slurry amounts should be between 5,000–17,900 m^3 yearly depending on SAT (see Table 133).

Acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save
2) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry
3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower)

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) decreases if acid amount per cubicmeter increases. While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The acid price by in-house SAT (128 € m^{-3}) is lower than by other SATs (157 € m^{-3}) and this is the reason why change of acid amount has smaller effect on cost-benefit by first SAT compared to others.

The calculations in paragraph 5.5 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts (Figure 50) show that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1} .

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount reaches the demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount per hectare and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. In-house acidification of cattle slurry has no positive cost-benefit by any type of artificial coverer. In-house acidification of pig slurry has positive cost-benefit compared to all cover types. Biggest cost-effect of in-house acidification of pig slurry is compared to rapseed oil, which is followed by tent and peat (Figure 113).

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises (see 5.9.4). N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises (see 5.9.5). The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises (see 5.9.6).

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system. The analysis model will be available on project website

5.10. Sweden

5.10.1. Animal number, Sweden

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. The acid price in the calculations is 128 € t^{-1} for in-house acidification and 157 € t^{-1} for in-storage and in-field acidification. N-fertilisers is AN34.4, 240 € t^{-1}. NS-fertiliser AXAN 27N+4S, 220 € t^{-1}. Thus N price 0.7 € kg^{-1} and S price 0.85 € kg^{-1}. The prices of project partner countries are between 0.48–1 and 0.11–0.85€ kg^{-1} respectively.

As a default value in Sweden is used 3% of Ntot lost as ammonia from storage with cattle slurry and 4% of tot-N from storage with pig slurry. (Personal contact with Lena Rodhe).

For Sweden, the in-house tehnology is calculated with presumption that acidification starts in slurry pumping pit in cattle and pig barn both. It means that there is not taken into account ammonia emission nor decrease of emission in barn. The calculations base on slurry N_{tot} content ex-housing. By Lena Rodhe the ex-housing and ex-storage data are close. Thus, the data published in report by Steineck et. al. (1999) are used in the calculations for all SATs. N_{tot} for conventional cattle slurry is 3.9 and pig slurry 5.1 kg t^{-1}. Instead of in-house SAT is used the term in-pit SAT for Sweden.

By the information from JH Agro presenter Holger Schulz is the price of in-pit acidification system for cattle and pig slurry is same as for cattle in-house acidification system. However, 5,000 € for additional mixer should be calculated in pumping pit, to mix slurry and acid during in-pit acidification. The slurry pump is controlled by acidification system to adjust slurry level in pit.

SAT producer suggests, that some acidified slurry should be in the pit, so that the new slurry from the barn flows into the prepared slurry. However, the process is more or less continious. After start of use of acidification system, the pit contains always some acidified slurry. The pit has to be so big that the amount of new slurry is only a small part (lower than 5 %) of the complete volume of the pit.

The other costs for in-pit SAT are same as by in-house SAT.

All three SATs have cost- benefit by cattle and pig slurry both in Sweden.

The minimal slurry amounts should be between 1,300–5,000 and 1,100–3,300. m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 146). The biggest reason for economic benefit of SAT-s is the cost of incorporation (50 € ha^{-1} in Sweden) of non-acidified slurry by disc harrow after spreading. If slurry amount is 30 m^3 ha^{-1}, then incorporation cost is 1.79 € m^{-3}, which is saved if acidified slurry is applied to the field surface and slurry is not incorporated to the soil.

Table 146. The minimum amount of slurry and corresponding amount of animal, by which the slurry acidification has cost-benefit.

SAT	Dairy cows: Number of animal	Dairy cows: Annual slurry amount, m^3	Fatteners: Number of animal per year	Fatteners: Annual slurry amount, m^3
In-pit	5,016	209	3,212	6,424
In-storage	1,320	55	1,123	2,245
In-field	3,672	153	3,257	6,513

Table 147. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount m^3 yr^{-1}	In-pit			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1,200	11.31	7.17	**-4.14**	7.36	7.17	**-0.19**	11.48	7.16	**-4.32**
2,400	7.04	5.95	**-1.09**	5.04	5.95	**0.91**	7.03	5.94	**-1.09**
9,000	3.41	4.17	**0.76**	2.60	4.18	**1.58**	3.02	4.17	**1.15**
12,000	2.88	3.86	**0.98**	2.26	3.87	**1.61**	2.55	3.86	**1.31**
21,000	2.23	3.33	**1.10**	1.74	3.33	**1.59**	1.85	3.32	**1.47**
24,000	2.07	3.21	**1.14**	1.64	3.22	**1.58**	1.71	3.20	**1.49**
33,000	1.81	2.95	**1.14**	1.42	2.95	**1.53**	1.44	2.94	**1.50**
48,000	1.53	2.67	**1.14**	1.20	2.67	**1.47**	1.17	2.66	**1.49**

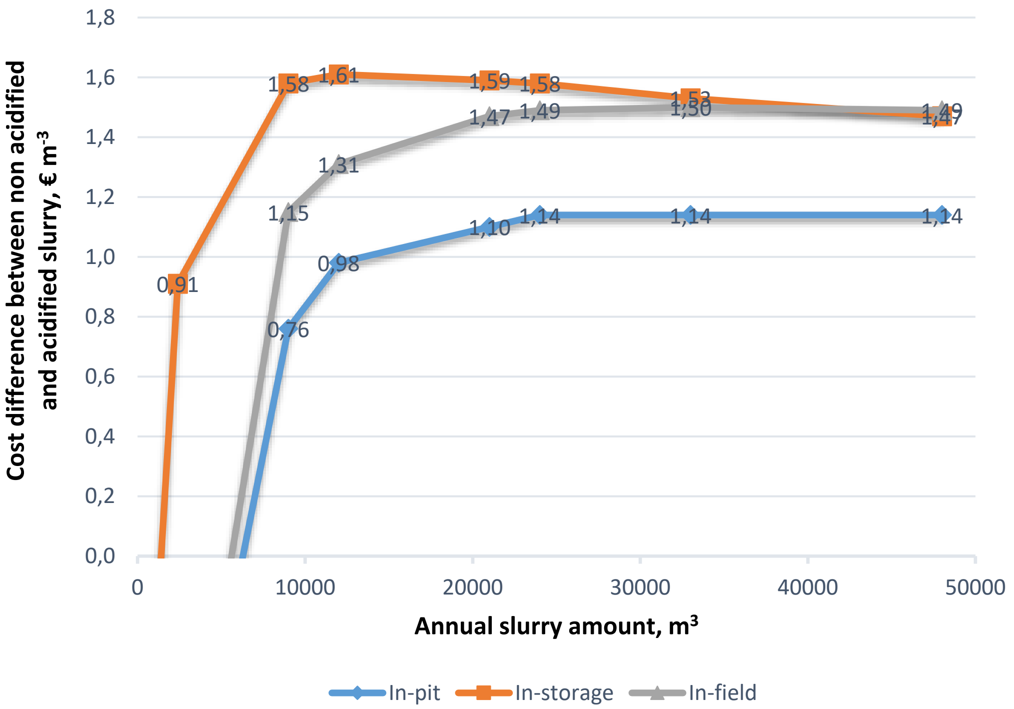

Figure 122. The cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Table 148. Fattener slurry handling costs if slurry is acidified and not acidified, and the cost decrease (€ m^{-3}) by use of cattle slurry acidification compared to disc-harrowing <12 h after band-application of non-acidified slurry.

Slurry amount	In-pit			In-storage			In-field		
m^3 yr^{-1}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
500	24.62	9.15	**-15.47**	11.99	9.09	**-2.90**	22.18	9.08	**-13.10**
2,500	6.76	5.96	**-0.80**	4.62	5.90	**1.28**	6.60	5.89	**-0.71**
5,000	3.98	4.96	**0.98**	3.14	4.91	**1.77**	4.10	4.89	**0.79**
9,000	2.59	4.25	**1.66**	2.27	4.19	**1.92**	2.78	4.18	**1.40**
21,000	1.38	3.40	**2.02**	1.41	3.35	**1.94**	1.61	3.33	**1.72**
33,000	0.95	3.03	**2.08**	1.09	2.97	**1.88**	1.20	2.96	**1.76**

Figure 123. The difference of fattener slurry handling costs if slurry is acidified and not acidified, € m^{-3} of slurry

5.10.2. Cover type, Sweden

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the chopped straw by cattle slurry and Hexa-cover plates by pis slurry gives slurry acidification lowest cost benefit. The figures 124 and 125 show also that the cost-benefit order of cover types for both, cattle and big slurries.

The required minimum manure storage capacity in Sweden is very much up to farm size but in general 10 month for pig farms and 8 month for cattle farms (part of the time the animals are outdoors in summer, several spreading opportunities during summer on grassland). However, larger farms could have harder demands (individual permits) and small farms a bit less storage period.

Table 149. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Cover type	In-pit Acid	 No acid	 **Dif.**

No cover	2.23	3.33	**1.10**
Chopped straw	2.27	3.43	**1.16**
Fibo clay balls	2.28	3.46	**1.18**
Floating foil	2.28	3.48	**1.20**
Hexa-cover plates	2.29	3.49	**1.20**
Peat	2.28	3.77	**1.49**
Rapeseed oil	2.28	4.33	**2.05**
Tent cover	2.29	3.85	**1.56**

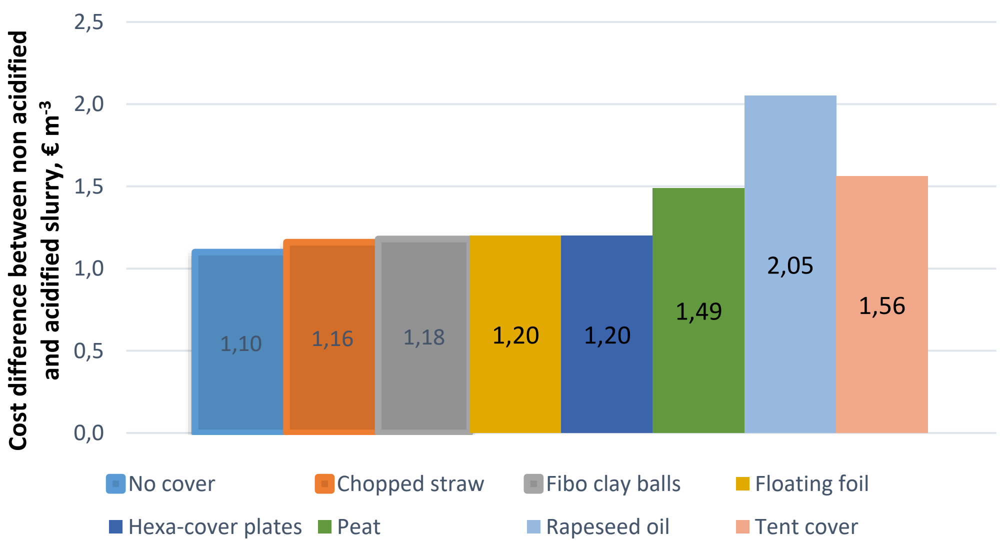

Figure 124. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

Table 150. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. Annual slurry amount 21,000 m^3.

	In-pit		
Cover type	Acid	No acid	**Dif.**
No cover	1.38	3.40	**2.02**
Chopped straw	1.64	3.50	**1.86**
Fibo clay balls (fraction 10-20 mm)	1.71	3.54	**1.83**
Floating foil	1.73	3.56	**1.83**
Hexa-cover plates	1.75	3.57	**1.82**
Peat	1.73	3.92	**2.19**
Rapeseed oil	1.71	4.62	**2.91**
Tent cover	1.77	4.01	**2.24**

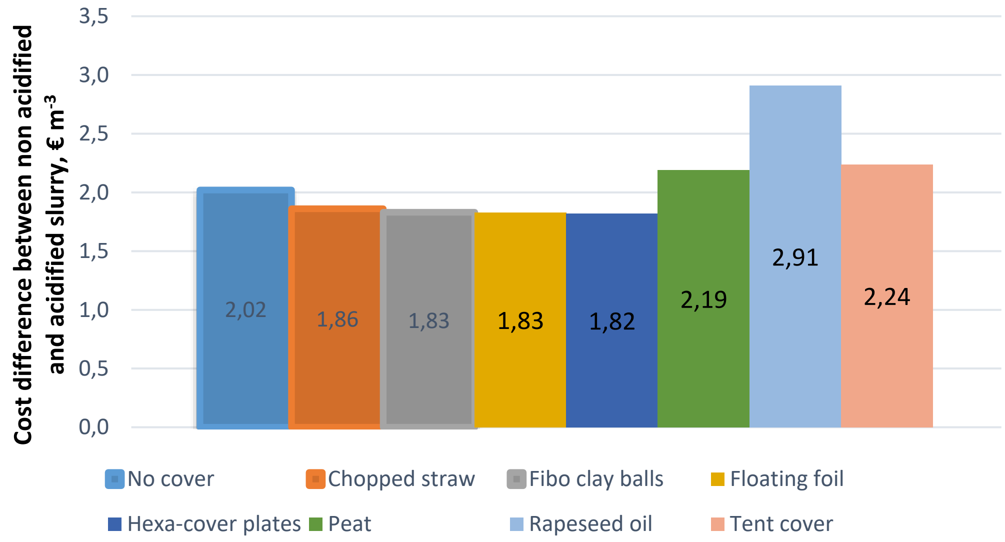

Figure 125. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry. In this analysis is varied with different type of storage covers by in-house acidification, if slurry is not acidified. 42,000 fatteners.

5.10.3. Acid consumption, Sweden

While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) decreases if acid amount per cubicmeter increases.

If acid consumption ↑ 1 l m^{-3}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-pit SAT:	↓0.25 € m^{-3}	↓0.25 € m^{-3}
in-storage SAT:	↓0.32 € m^{-3}	↓0.31 € m^{-3}
in-field SAT:	↓0.32 € m^{-3}	↓0.32 € m^{-3}

Acid content change in slurry has lowest impact by in-house SAT and biggest by in-field SAT. The reason is that the acid price for in-house SAT is lower (128 € t^{-1}) than by other SATs (157 € t^{-1}).

Table 151. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount	In-pit			In-storage			In-field		
l m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	1.45	3.33	**1.88**	1.07	3.33	**2.26**	1.37	3.32	**1.95**

3	1.78	3.33	**1.55**	1.53	3.33	**1.80**	1.85	3.32	**1.47**
4	2.08	3.33	**1.25**	1.88	3.33	**1.45**	2.21	3.32	**1.11**
5	2.37	3.33	**0.96**	2.24	3.33	**1.09**	2.58	3.32	**0.74**
7	2.96	3.33	**0.37**	2.95	3.33	**0.38**	3.31	3.32	**0.01**

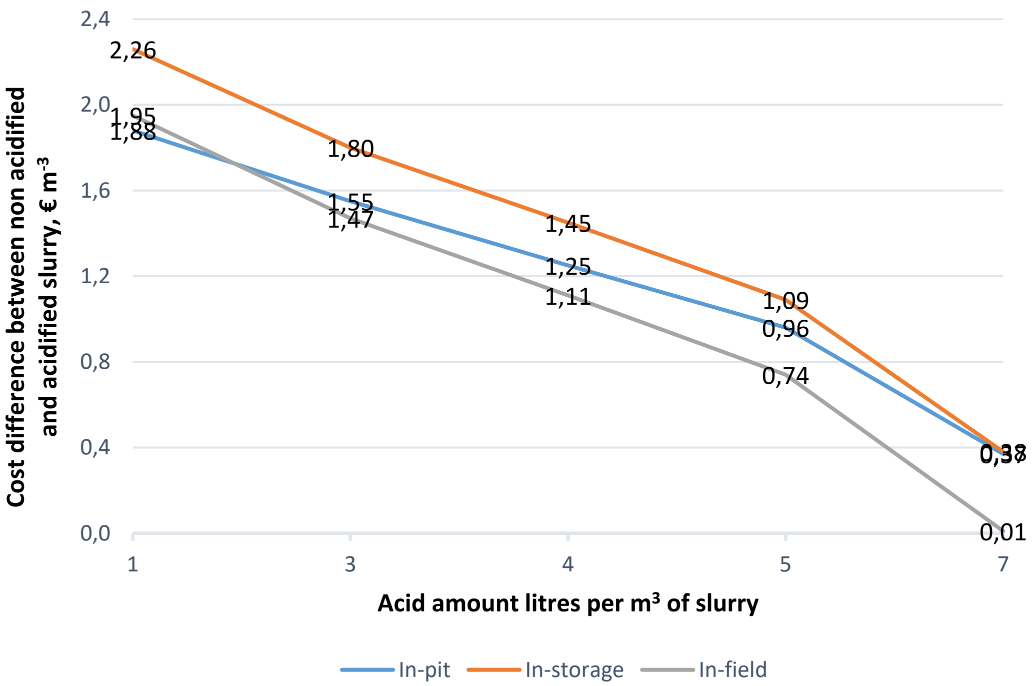

Figure 126. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

Table 152. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption.

Acid amount	In-pit			In-storage			In-field		
l m^{-3}	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
1	0.89	3.40	**2.51**	0.95	3.35	**2.40**	1.27	3.33	**2.06**
3	1.23	3.40	**2.17**	1.41	3.35	**1.94**	1.75	3.33	**1.58**
4	1.52	3.40	**1.88**	1.77	3.35	**1.58**	2.12	3.33	**1.21**
5	1.82	3.40	**1.58**	2.13	3.35	**1.22**	2.48	3.33	**0.85**
7	2.40	3.40	**1.00**	2.84	3.35	**0.51**	3.21	3.33	**0.12**

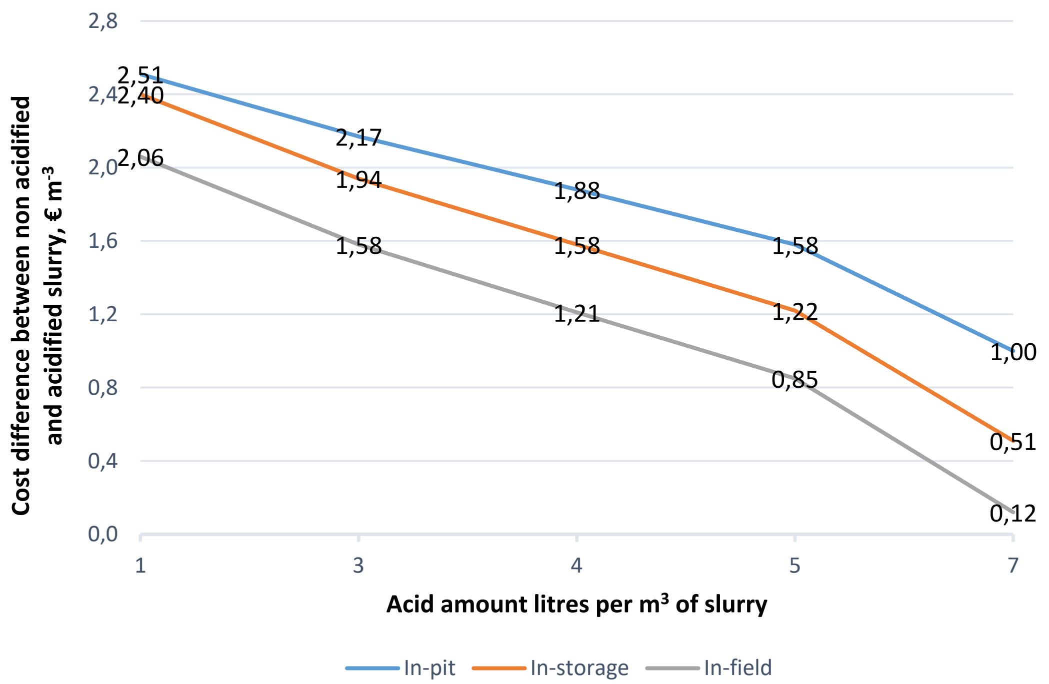

Figure 127. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on acid consumption

5.10.4. N_{tot} in slurry, Sweden

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises.

If N_{tot} content in slurry ↑ 1 kg m^{-3} , then SAT cost-benefit by

	cattle slurry	pig slurry:
in-pit SAT:	↑0.1 € m^{-3}.	↑0.2 € m^{-3}.
in-storage SAT:	↑0.11 € m^{-3}.	↑0.12 € m^{-3}.
in-field SAT:	↑0.09 € m^{-3}	↑0.09 € m^{-3}.

N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-pit sat of pig slurry. The reason is that by in-house or in-pit acidification of pig slurry is the ammonia emission reduction effect highest, 64%.

Table 153. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-pit			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
3	2.31	3.31	**1.00**	1.83	3.32	**1.49**	1.92	3.31	**1.39**
4	2.22	3.33	**1.11**	1.73	3.33	**1.60**	1.84	3.32	**1.48**
5	2.13	3.34	**1.21**	1.63	3.35	**1.72**	1.76	3.33	**1.57**
6	2.04	3.35	**1.31**	1.53	3.36	**1.83**	1.68	3.34	**1.66**

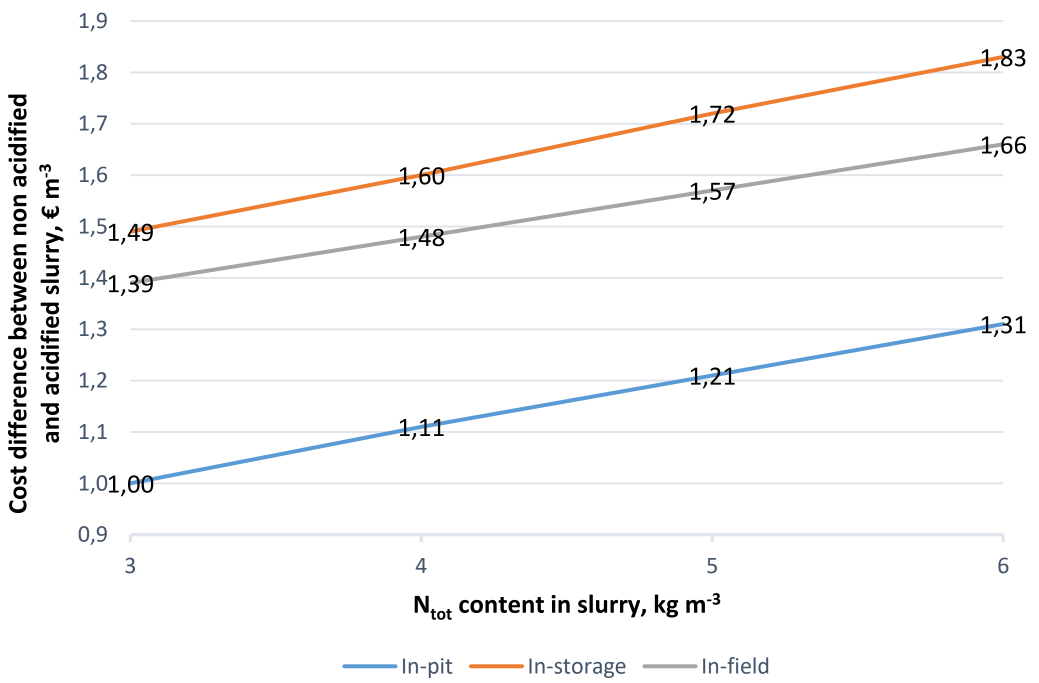

Figure 128. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Table 154. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

Ntot content kg m^{-3}	In-pit			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
4	1.57	3.38	**1.81**	1.52	3.33	**1.81**	1.69	3.32	**1.63**
5	1.39	3.40	**2.01**	1.42	3.35	**1.93**	1.61	3.33	**1.72**
6	1.22	3.43	**2.21**	1.33	3.36	**2.03**	1.54	3.34	**1.80**
7	1.05	3.45	**2.40**	1.23	3.38	**2.15**	1.46	3.36	**1.90**

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises.

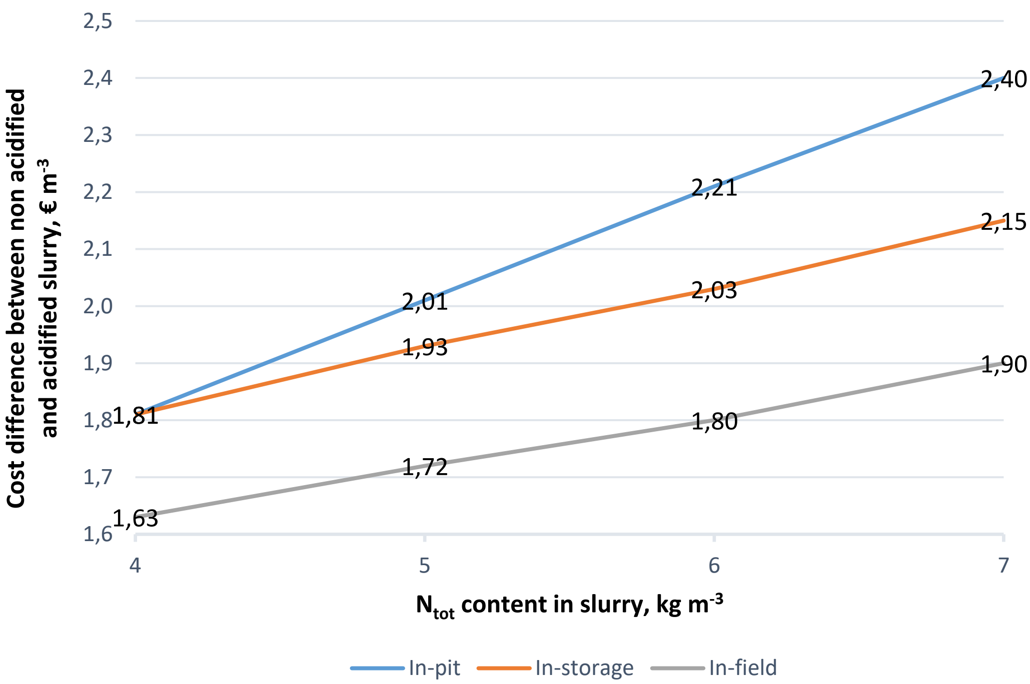

Figure 129. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending N_{tot} content in slurry

5.10.5. N price, Sweden

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises.

N price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-pit SAT:	↑0.043 € m^{-3}.	↑0.11 € m^{-3}.
in-storage SAT:	↑0.046 € m^{-3}.	↑0.06 € m^{-3}.
in-field SAT:	↑0.037 € m^{-3}	↑0.05 € m^{-3}.

The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-pit sat of pig slurry. The reason is that by in-house or in-pit acidification of pig slurry is the ammonia emission reduction effect highest, 64%.
Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

Table 155. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-pit			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.35	2.38	3.33	**0.95**	1.91	3.33	**1.42**	1.98	3.32	**1.34**
0.56	2.29	3.33	**1.04**	1.81	3.33	**1.52**	1.90	3.32	**1.42**

0.7	2.23	3.33	**1.10**	1.74	3.33	**1.59**	1.85	3.32	**1.47**
0.84	2.17	3.33	**1.16**	1.68	3.33	**1.65**	1.80	3.32	**1.52**
1.05	2.08	3.33	**1.25**	1.58	3.33	**1.75**	1.72	3.32	**1.60**

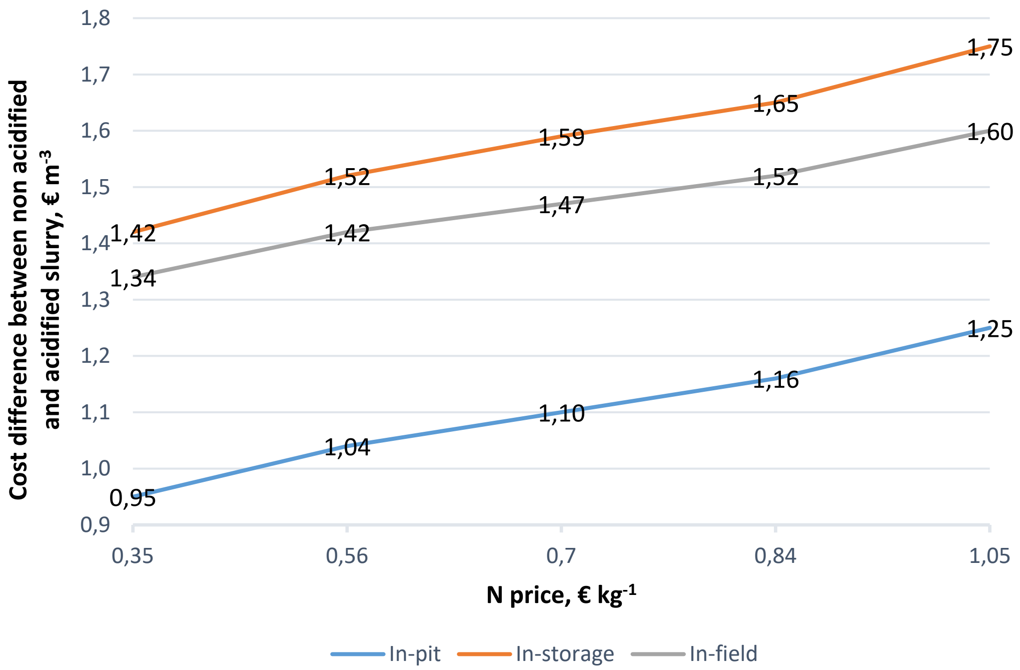

Figure 130. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

Table 156. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

N price € kg^{-3}	In-pit			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.35	1.75	3.40	**1.65**	1.63	3.35	**1.72**	1.78	3.33	**1.55**
0.56	1.53	3.40	**1.87**	1.50	3.35	**1.85**	1.68	3.33	**1.65**
0.7	1.38	3.40	**2.02**	1.42	3.35	**1.93**	1.61	3.33	**1.72**
0.84	1.23	3.40	**2.17**	1.33	3.35	**2.02**	1.54	3.33	**1.79**
1.05	1.00	3.40	**2.40**	1.20	3.35	**2.15**	1.44	3.33	**1.89**

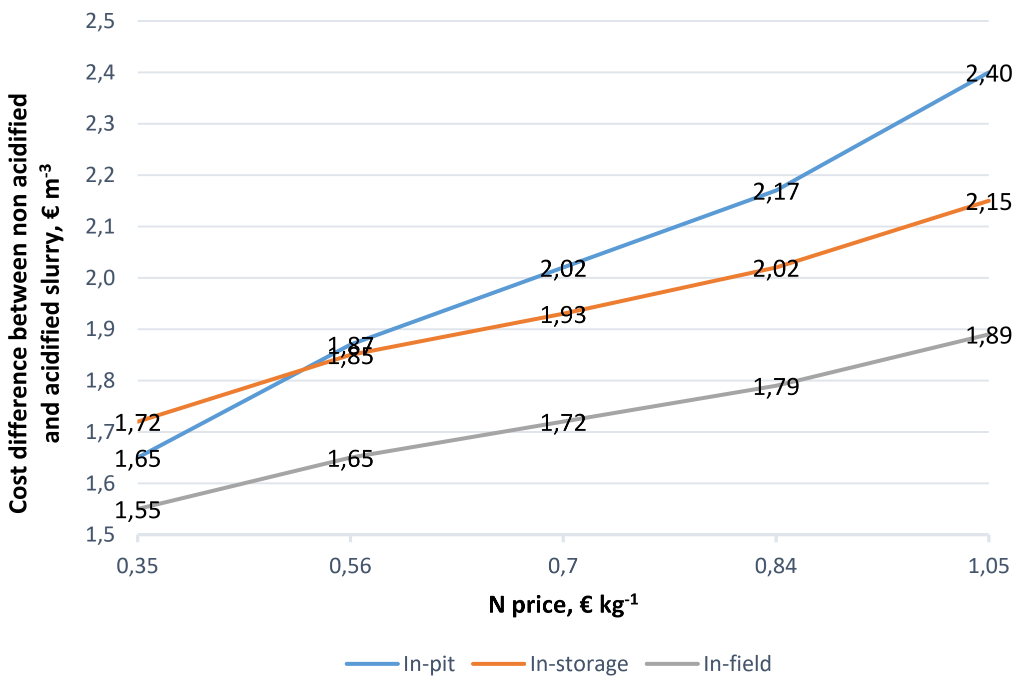

Figure 140. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on N price

5.10.6. S price, Sweden

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

S price in mineral fertilisers ↑ 0.1 € kg^{-1}, then SAT cost-benefit by

	cattle slurry	pig slurry:
in-pit SAT:	↑0.08 € m^{-3}.	↑0.08 € m^{-3}.
in-storage SAT:	↑0.08 € m^{-3}.	↑0.08 € m^{-3}.
in-field SAT:	↑0.08 € m^{-3}	↑0.08 € m^{-3}.

The change of S price in mineral fertilisers has same impact by different SATs and slurry types.

Table 157. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-pit			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.425	2.58	3.33	**0.75**	2.10	3.33	**1.23**	2.21	3.32	**1.11**
0.68	2.37	3.33	**0.96**	1.89	3.33	**1.44**	1.99	3.32	**1.33**
0.85	2.23	3.33	**1.10**	1.74	3.33	**1.59**	1.85	3.32	**1.47**
1.02	2.09	3.33	**1.24**	1.60	3.33	**1.73**	1.71	3.32	**1.61**
1.275	1.87	3.33	**1.46**	1.39	3.33	**1.94**	1.50	3.32	**1.82**

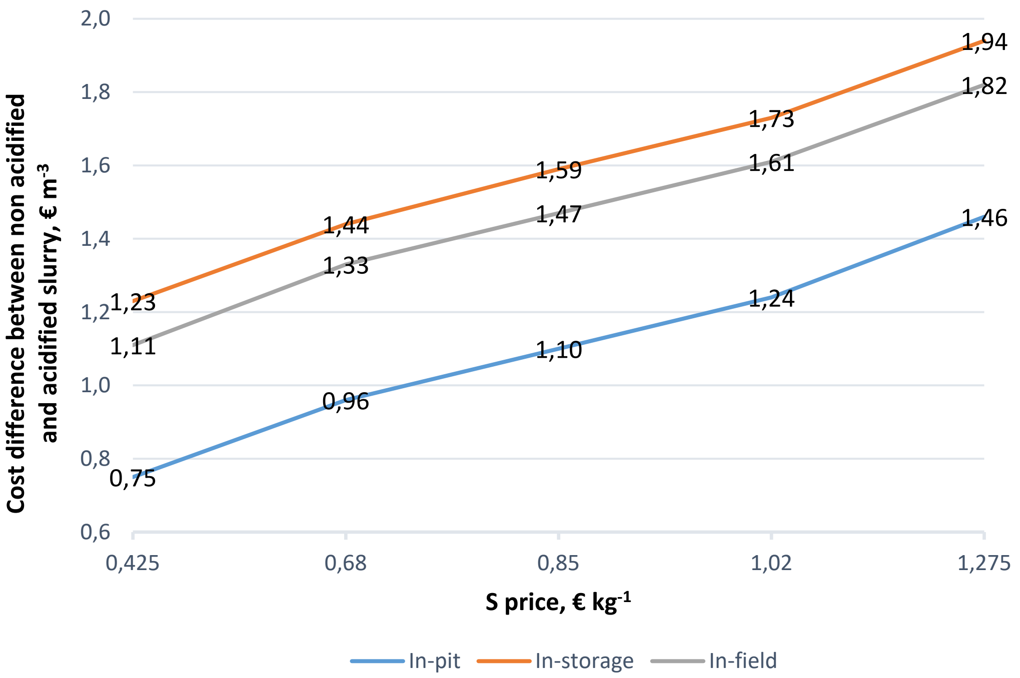

Figure 150. Dairy cow slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

Table 158. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

S price € kg^{-3}	In-pit			In-storage			In-field		
	Acid	No acid	**Dif.**	Acid	No acid	**Dif.**	Acid	No acid	**Dif**
0.425	1.73	3.40	**1.67**	1.77	3.35	**1.58**	1.96	3.33	**1.37**
0.68	1.52	3.40	**1.88**	1.56	3.35	**1.79**	1.75	3.33	**1.58**
0.85	1.38	3.40	**2.02**	1.42	3.35	**1.93**	1.61	3.33	**1.72**
1.02	1.24	3.40	**2.16**	1.28	3.35	**2.07**	1.47	3.33	**1.86**
1.275	1.02	3.40	**2.38**	1.06	3.35	**2.29**	1.26	3.33	**2.07**

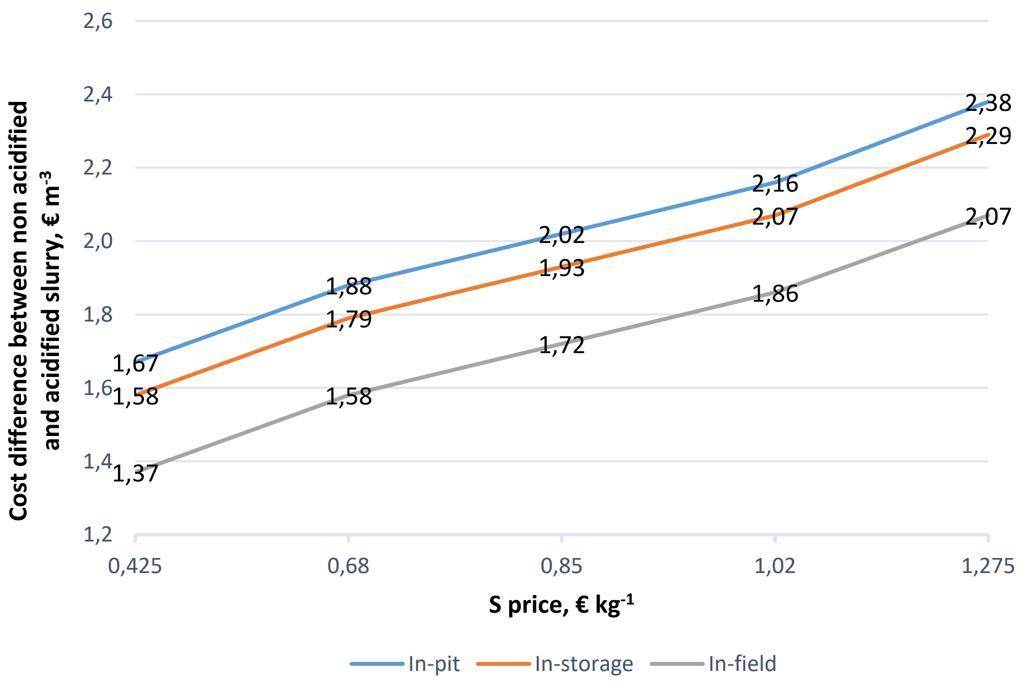

Figure 151. Fatteners slurry handling costs if slurry is acidified and not acidified, and the difference of costs € m^{-3} of slurry, depending on S price

5.10.7. Summary, Sweden

For Sweden, the in-house tehnology is calculated with presumption that acidification starts in slurry pumping pit in cattle and pig barn both. It means that there is not taken into account ammonia emission nor decrease of emission in barn. The calculations base on slurry N_{tot} content ex-housing. By Lena Rodhe the ex-housing and ex-storage data are close. Thus, the data published in report by Steineck et. al. (1999) are used in the calculations for all SATs. N_{tot} for conventional cattle slurry is 3.9 and pig slurry 5.1 kg t^{-1}. Instead of in-house SAT is used the term in-pit SAT for Sweden.

By the information from JH Agro presenter Holger Schulz is the price of in-pit acidification system for cattle and pig slurry is same as for cattle in-house acidification system. However, 5,000 € for additional mixer should be calculated in pumping pit, to mix slurry and acid during in-pit acidification. The slurry pump is controlled by acidification system to adjust slurry level in pit.

SAT producer suggests, that some acidified slurry should be in the pit, so that the new slurry from the barn flows into the prepared slurry. However, the process is more or less continious. After start of use of acidification system, the pit contains always some acidified slurry. The pit has to be so big that the amount of new slurry (which requires acidification) is only a small part (lower than 5 %) of the complete volume of the pit.
The other costs for in-pit SAT are same as by in-house SAT.

Analysed is the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry. All three SATs have cost- benefit by cattle and pig slurry both in Sweden. The minimal slurry amounts should be between 1,300–5,000 and 1,100–3,300. m^3 yearly for cattle and pig slurry correspondingly, depending on SAT (see Table 146).

The biggest reason for economic benefit of SAT-s is the cost of incorporation (50 € ha^{-1} in Sweden) of non-acidified slurry by disc harrow after spreading. If slurry amount is 30 m^3 ha^{-1}, then incorporation cost is 1.79 € m^{-3}, which is saved if acidified slurry is applied to the field surface and slurry is not incorporated to the soil.

Acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save
2) the in-pit SAT has higher reduction effect on NH_3 emission from pig slurry
3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower).

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) decreases if acid amount per cubicmeter increases. While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The acid price by in-pit SAT (128 € m^{-3}) is lower than by other SATs (157 € m^{-3}) and this is the reason why change of acid amount has smaller effect on cost-benefit by first SAT compared to others.

The calculations in paragraph 5.10 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts (Figure 50) show that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1} .

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 cattle slurry by in-house or in-pit SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount is reaches demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-pit acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-pit acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, the in-pit slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the chopped straw by cattle slurry and

Hexa-cover plates by pis slurry gives slurry acidification lowest cost benefit. The figures 124 and 125 show also that the cost-benefit order of cover types for both, cattle and big slurries.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises (see 5.10.4). N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-pit sat of pig slurry. The reason is that by in-pit acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises (see 5.10.5). The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-pit sat of pig slurry. The reason is that by in-pit acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises (see 5.10.6).

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system. The analysis model will be available on project website.

6. Summary of results, conclusions and recommendations

6.1.1. Summary of results

The economic aspects have a crucial role for the farmer’s decision to choose one of acidification technologies (SAT) or some other solution to minimise ammonia emission from slurry. The calculation models are composed within project to compare different solutions. Excel applications are built on bases of these models. Present report gives overview about data and methods used in analysis models. The calculation results are presented for every country participating in Baltic Slurry Acidification project. The analysis model and report are available on project website balticslurry.eu.

In all countries were analysed the cost-benefit of SATs compared to disc-harrowing <12 h after band-application of non-acidified slurry.

All three SATs have cost- benefit by pig slurry in all countries by bigger slurry amounts. All three SATs have cost- benefit by cattle slurry in most countries. The smallest minimum slurry amount was 1,100 m^3 yearly in Sweden by in-storage acidification of pig slurry.

In Lithuania the cattle slurry acidification had no cost-benefit compared to non-acidified and incorporated slurry by any SAT and slurry amount. In some countries cattle slurry acidification had has cost-benefit only by some SAT (Belarus, Latvia and Russia).

In, Lithuania, the main reason for negative cost-benefit was mainly very high liming costs - 175 € t^{-1}. Another reason is relatively low S price compared to other project countries (0.15 € kg^{-1} and 0.11–0.85 € kg^{-1}).

The in-house acidification has in Belarus significantly higher cost-benefit comapred to other SATs. The reason is that by in-house SAT is used bulk acid which is transported by big tank truck and has much lower price (30 € t^{-1}) compared to transportation in the IBC tanks (101 € t^{-1}), which is used by other SATs.

In Latvia and Russia the small cost-benefits were caused by low mineral N and S prices, and low slurry incorportion cost.

For Denmark, analysed was the cost-benefit of acidified slurry compared to non-acidified slurry if they both are band-spreaded, but the non-acidified slurry is

A) not incorporated after band-application or

B) incorporated by disc-harrow <12 h after band-application.

The results show that by both incorporation scenarios of non-acidified slurry, the slurry acidification has cost-benefit compared to non-acidification. The reason for high cost-benefits is relatively high price of mineral N and S (1 and 0.65 € kg^{-1}) in Denmark compared to other countries (0.48–0.79 and 0.11–0.41 € kg^{-1}). However, the cost-benefit of SATs by scenario A was 0.87–1.26 € kg^{-1} lower than in scenario B, because of smaller tillage cost (50 € ha^{-1}).

For Sweden, the in-house tehnology is calculated with presumption that acidification starts in slurry pumping pit in cattle and pig barn both. It means that there is not taken into account ammonia emission nor decrease of emission in barn. The calculations base on slurry N_{tot} content ex-housing.

By the information from JH Agro presenter Holger Schulz is the price of in-pit acidification system for cattle and pig slurry is same as for cattle in-house acidification system. However, 5,000 € for additional mixer should be calculated in pumping pit, to mix slurry and acid during in-pit acidification. The other costs for in-pit SAT are same as by in-house SAT.

All three SATs have cost- benefit by cattle and pig slurry both in Sweden. The biggest reason for economic benefit of SAT-s is the cost of incorporation (50 € ha^{-1} in) of non-acidified slurry by disc harrow after spreading.

In all countries the acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save
2) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry
3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower).

The cost-benefit of acidified slurry per cubicmeter (€ m^{-3}) increases if acid amount per cubicmeter decreases. While the acid cost is biggest running cost, then the amount of acid required to lower slurry acidity to target pH (see Table 8) has essential impact on cost-benefit of slurry acidification. The acid price by in-house or in-pit SAT is lower than by other SATs (except Russia) and this is the reason why change of acid amount has smaller effect on cost-benefit by first SAT compared to others. The reason for lower acid cost by in-house SAT is the use of bulk acid which is transported by big tank truck and has lower price compared to transportation in the IBC tanks (except Russia).

The calculations in chapter 5 were done by slurry amount 30 m^3 ha^{-1}. The extra calculations made for Finland for different hectare amounts show (Figure 50) that cost-benefit of in-house SAT is higher if slurry amount is 20 or 10 m^3 ha^{-1}.

One reason is that the slurry incorporation cost per hectare is constant despite of slurry amount per hectare. Thus, the smaller is slurry amount per hectare the higher is incorporation cost per cubicmeter of non-acidified slurry.

Another aspect, why low amount of acidified slurry give higher economic effect, is the effective use of S applied with acidified slurry. In the calculations is used 4.5 liter acid per m^3 of cattle slurry by in-house SAT. If the slurry amount is 30, 20 and 10 m^3 ha^{-1} then the S amount applied to the field is 80, 53 and 26 kg ha^{-1} correspondingly. The S need for crops is in calculations 25 kg ha^{-1} in average. The costs on mineral S are reduced if acidified slurry is applied and the reduction effect is calculated until S amount reaches the demand of crop. After that S cost reduction stays constant and the S amount what exceeds crop need, is not taken into calculation. However, the S cost reduction value is always divided by slurry amount per hectare and if the cost reduction is constant then by growing hectare amount of slurry the S cost reduction per cubicmeter of slurry decreases.

An alternative to in-house acidification to minimise the ammonia emission from slurry storage is to cover storage. The cost calculations made for different type of storage covers shows that cost benefit by in-house acidified slurry depends on capital cost and ability to decrease the ammonia emission. The rapeseed oil has highest capital cost and decreases 80% of ammonia emission (Table 21). Thus, in all countries the in-house slurry acidification gives biggest cost effect compared to this type of cover, which is followed by tent and peat. Compared to the Hexa-cover plates gives slurry acidification lowest cost-benefit in most countries.

For Denmark, analysed was the cost-benefit of slurry acidification, compared to non-acidified slurry which is stored under cover but not incorparated after band-application (figures 25 and 27). The results show that in this case the cost-benefit decreases compared to the case if slurry is covered and incorporated both.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N_{tot} content in slurry rises. N_{tot} content change in slurry has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry the ammonia emission reduction effect is highest, 64%.

The cost-benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if N price in mineral fertilisers rises. The change of N price in mineral fertilisers has lowest impact by in-field SAT and biggest by in-house sat, especially in the case of pig slurry. The reason is that by in-house acidification of pig slurry is the ammonia emission reduction effect highest, 64%. Bigger effect by pig slurry compared to cattle slurry is caused also by the higher N_{tot} content of pig slurry and thus N-savings by SAT-s.

The cost benefit per cubicmeter of acidified slurry (€ m^{-3}) increases if S price in mineral fertilisers rises.

Although the present example shows cost benefit of slurry acidification by bigger slurry amounts, a careful analysis with local parameters and future prices should be performed before deciding to invest to acidification system.

6.1.2. Conclusions

The impact of different aspects on cost-benefit of slurry acidification were calculated or collected during economic analyses. The overview of conclusions is collected to the table 151.

Table 151. Directions of change of aspects to increase cost-benefit of slurry acidification

The aspect	Direction of change of aspect to increase cost-benefit of slurry acidification
Acidified slurry amount yearly, $m^3\ yr^{-1}$	↑
N_{tot} content in slurry, kg m^{-3}	↑
pH of slurry	↑
Mineral N price cost (fertiliser plus handling)	↑
Mineral S price (fertiliser plus handling)	↑
Crop S demand	↑
Slurry incorporation cost per hectare, if in reference scenario the non-acidified slurry is incorporated after application.	↑
Slurry storage cover cost per cubicmeter of slurry, if in reference scenario the non-acidified slurry is covered with artificial cover. In the case of inhouse or in-pit acidification.	↑
Outside temperature during slurry application (ALFAM).	↑
Wind speed during slurry application, (ALFAM).	↑
Opnened area of slurry in slurry storage, per cubicmeter of slurry. In the case of in-house or in-pit acidification..	↑
Slurry amount per hectare (ALFAM), if a) in reference scenario the non acidified slurry is not ncorporated after application b) S amount applied with acidified slurry doesn't	↑

exceed S need of crops	
SAT investment cost	↓
Organic matter content of slurry (ALFAM).	↓
Sulphuric acid price in farm gate.	↓
Sulphuric acid demand per cubimeter of slurry	↓
Slurry amount per hectare, if a) in reference scenario the non acidified slurry is incorporated after application b) S amount applied with acidified slurry exceeds S need of crops	↓
S content of slurry before acidification	↓
Liming cost per hectare	↓

The acidification of pig slurry has higher economic benefit compared to cattle slurry, because

1) pig slurry contains more NH_4-N to save
2) the in-house SAT has higher reduction effect on NH_3 emission from pig slurry
3) the acid need of pig slurry is lower
4) the risk to exceed S need of plants is lower (because the acid amount is lower).

The calculation model doesn't take into account the ammonia emission during slurry mixing in storage. Suggestable is to improve the calculation model so that in the future the model calculate also nitrogen loss with ammonia emission during mixing if cost-benefit of in-house, in-pit or in-storage acidification is analysed.

The average ammonia emission values in stable, storage and field depend among othres on weather conditions. Thus in countries with different climate, the values are different. Reccomendable is to use in calculations country based ammonia emission values. The calculations made for present report are made with emission values shown in tables 11, 12 and 13.

6.1.3. Recommendations

The previous economc analyses gives overview about conditions by which the slurry acidification has cost-benefit compared to non-acidified slurry. However, a careful analysis with local parameters and prices should be performed before deciding to invest to acidification system.

Recommended is before investing to SAT to

1) make slurry analyses for N, S and dry matter content and pH.
   a. If in-house SAT is planned , then data about ex-animal slurry,

b. if in-pit SAT then data about ex-housing slurry and

c. if in-storage or in-field SAT is planned, then data about ex-storage slurry are required.

2) ask from laboratory slurry titration using sulphuric acid, to learn acid need per cubicmeter of slurry, it would be good to use acid with same quality as planned to use in the farm,

3) define slurry amount planned to acidify,

4) clarify acid price at farm gate, if acid is delievered by tank truck and IBC tank,

5) ask sulpuric acid quality certificate from acid provider, be sure that acid doesn't contain components harmful to the soil or plant (like heavy metals),

6) define security of supply of acid

7) define crops and their S need planned to fertilise with acidified slurry,

8) define, when the crops need N and S,

9) define mineral N and S costs in field (fertiliser price plus handling costs)

10) define liming cost of fields planned to fertilise with acidified slurry

11) define cost of alternative ammonia emission abating technologies like slurry injection or incorporation, or storage covering

12) discuss carefully with SAT producer about technical, safety and economical aspects of establishing, maintainance and use of SAT.

13) calculate cost-benefit of use of acidified slurry in farm.

Several slurry handling operations like mixing, transportation and spreading can be ordered from service provider. The in-storage and in-field acidification are also possible to provide as services. Recommended is before investing to slurry acidification technogy as service provider to:

1) define possible client farms and slurry amounts planned to acidify yearly,

2) discuss carefully with SAT producer about technical, safety and economical aspects of purchising, maintainance and use of SATs.

3) calculate the cost-benefit of use of acidified slurry in clients farms (see the list below)

4) advice clients about slurry acidification agronomical, economical and safety aspects so that clients and service provider both achive positive result from slurry acidification service.

If slurry amount in the farm is smaller than required to achive the cost-benefit of farm-own acidification system, then is suggestable to analyse the possibility to use acidification service from service provider. Service provider can offer in-storage or in-field acidification. Recommended is before ordering slurry acidification service to:

1) define slurry acidification service cost
2) make ex-storage slurry analyses for N, S and dry matter content and pH,
3) ask from laboratory slurry titration using sulphuric acid, to learn acid need per cubicmeter of slurry, it would be good to use acid with same quality as planned to use in the farm,
4) ask sulpuric acid quality certificate from service provider, be sure that acid doesn’t contain components harmful to the soil or plant (like heavy metals),
5) define slurry amount planned to acidify,
6) define crops and their S need planned to fertilise with acidified slurry,
7) define, when N and S need of the crops,
8) define mineral N and S costs in farm (fertiliser price plus handling costs)
9) liming cost of fields planned to fertilise with with acidified slurry
10) define cost of alternative ammonia emission abating technologies like slurry incorporation or storage covering.
11) calculate cost-benefit of use of acidified slurry in farm.

To maximise the cost-benefit of slurry acidification is important to minimise the impact of cost-benefit decreasing factors and and maximise impact of cost-benefit increasing factors.

The biggest running cost is acid cost. To minimise acid cost is important to use minimum amount of acid per cubicmeter of slurry, required to achive optimal level of ammonia emission.

If after slurry application is planned to till soil anyway is recommendable to use acid amount by S need of crops.

If weather conditions are favourable for ammonia emission and in-storage or in-field acidification are used, then is recommendable to adjust acid amount by minimum ammonia emission level.

If farm has several stables and slurry storages but only some of them use in-house acidification system, then is recommendable to apply acidified slurry to fields with growing crops and weather conditions are favourable for ammonia emission. The non-acidified slurry can be applied if weather conditions are not favourable for ammonia emissions or slurry is incorporated to the soil.

By planning the use of acidified slurry should be taken into the account among others the

1) S content of acidified slurry
2) S demand of crops in total and depending on growth stage

Optimal would be to adjust slurry amount among other nutrients also by S need of crops, because if S amount applied with acidified slurry exceeds amount required by plants, then:

1) cost-benefit of slurry acidification decreases
2) excess S in soil is leaching, which in long term can cause acidification of soil and unpleasant odour of groundwater.

If slurry is applied to the fields in early spring when slurry storages are emptied first time after winter, then the growth of crops is not very fast or they are not drilled yet. Thus, the consumption of nutrients is low, and nutients not consumed are free to leach after rainfalls. Another aspect is that the ammonia emission depends on air temperature (ALFAM) and this is the reason why in calm chilly days on early spring the emission is low.

Thus, recommendable is to make in-field and in-storage acidification in early spring by S demand of crops. However, if possible, would be better to divide the yearly slurry amount planned to the crop between several applications, because then is possible to apply S and N in amount needed by crop until next slurry application and decrease the risk that some amount from N and S depot is leaching before uptake by plants. By divided slurry application the acidified slurry has advantages compared to non-acidified slurry because

1) suggestable is to use acidified slurry if air temperature is high (this causes high ammonia emissions if slurry is not acidified). Thus, if slurry is applied in late spring or in summer, then probably the ammonia emission abating effect of acidification is high and crops have power to consume movable N and S in bigger amount than in early spring. It helps also to minimise the amount of excess free N and S compounds in soil and risk of leaching of these compunds by use of acidified slurry.;
2) the incorporation of acidified slurry is not required. The slurry applied on field with growing of crops cannot be incorporated and the only possibilty is surface spreading without incorporation or disc-injection. The surface spreading by broadcast or band-spreader is cheaper, because spreading performance is higher and spreader cost per unit of work width is lower than by injection. Also number of tracks on field is smaller (wider spreader) and damage of plants are less compared to use of injector.

Thus, if 1) the slurry is planned to apply without incorporation, 2) during slurry acidification the weather conditions are favourable for ammonia emission and 3) crop is able to consume applied N and S, then the use of acidified slurry is recommendable.

In autumn if slurry is applied to the fields where nutrient uptake by crops is poor or or is without growing crop, then the risk of leaching of free S and N compounds is high. In autumn the weather conditions are not favourable for high ammonia emission during field application.

Thus, the application of acidified slurry in late autumn is not recommendable also from economic point of view because crop N and S demand is low and mineral N and S cost reducing effect of acidified slurry is modest.

By use of in-pit SAT is recommendable to analyse optimal timing of slurry acidification. In that SAT the slurry is pumped from stable to separate tank (named also as slurry pit, which gives the name to the SAT), acidified and then pumped forward to the slurry storage. In nordic condition, if slurry storage is covered with ice or snow, then ammonia emission is abated. Thus, in that period the slurry acidification has no economic effect in meaning of reducing mineral N costs.

After winter, the slurry strorages are emptied 1) to make space for new slurry cumulating during next season and 2) to supply crops with nutrients before growing season.

If the soil tillage is made anyway before establishing of crop, then combining the slurry application and soil tillage help to spare time and labour cost. The combnination of these two operations is known also as incorporation spreading. Incorporation of acidified slurry dos not give economic effect of slurry acidification in meaning of reduction of tillage costs. And N loss is abated anyway thanks to to use of incorporations spreading.

In point of view of reducing mineral N costs, the surface spreading of slurry without incorporation has economic benefit compared to non-acidified slurry. The use of acidified slurry has bigger chance to have cost-benefit compared to non-acidified slurry if it is applied on fields with growing crops where slurry incorporation is not possible.

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Appendix 1. Acid tank foundation cost items

Cost type	Quantity	Unit	Unit Price [EUR]	Total [EUR]
OUTSIDE WORKS				**12 776,74**
Preparation and demolition				**347,00**
Preparation and land cleaning				
Preparation works	1	obj	347,00	347,00
Hole under building				**620,21**
Dig outs				
Dig out 600mm	26,4	m3	5,90	155,76
Soil backfill				
Backfill with sand for concrete slab foundation	19,2	m3	18,36	352,51
Soil transportation				
Soil transportation	26,4	m3	4,24	111,94
Exterior structures				**5 552,28**
Channels, wells, pools, tanks				
Gravel under concrete slab, 200mm	9,6	m3	30,14	289,34
Geotextile membrane	42	m2	6,14	257,88
Concrete slab foundation C35/45 4000*10000*200 mm reinforcement 10/150*150*2	8	m3	314,00	2 512,00
Concrete surrounding edge for concrete slab C35/45 150*200*28000mm	0,84	m3	389,00	326,76
Floor drain installation for concrete slab	1	set	43,20	43,20
Protection columns for tank perimeter, measurement 100*100*6mm, Zn, h-800mm	10	set	47,31	473,10
Installation of sulphuric acid tank (tank is customer delivery)	1	set	1 650,00	1 650,00
Exterior services				**6 257,25**
Exterior sewerage				
Installation of sewerage pipelines d=100mm with dig outs, base layers, backfill and surface coverings	25	jm	89,14	2 228,50
Exterior water pipes		m		
Installation of water pipelines d=32mm with dig outs, base layers, backfill and surface coverings	25	m	78,14	1 953,50
Heating cable with installation	25	m	24,14	603,50
Shower with water tap	1	set	142,00	142,00

Electrical power cables				
Installation of main power line cable with dig outs, base layers, backfill and surface coverings	25	m	36,14	903,50
Main power line and heating cable connection in switchboard	1	set	240,00	240,00
Electrical low-current cables				
Communication cable inside main powerline trench	25	m	7,45	186,25
BUILDING SITE ARRANGEMENT				**1 847,00**
Building site arrangement costs	1	obj	1 847,00	1 847,00
				14 623,74

The calculation are made by Estonian company Eelarvestusgrupp OÜ in February 2018.

The company notes are:

The length of exterior services will change, price estimation includes 25 metres

Price estimation is based on sketch drawings

Price estimation accuracy +/- 15%.

Appendix 2. Information about sulphuric acid producing plants in Baltic Sea region

Plants, producing sulphuric acid are shown on the web page “Acid Plant Database”. (http://www.sulphuric-acid.com/sulphuric-acid-on-the-web/acid%20plants/Acid_Plant_Index.htm).

By this web page there isn’t any producer in Denmark, Estonia and Latvia.

Belarus
Gomel Chemical Plant – in Gomel
JSC Grodno Azot - in Grodno
JSC Naftan Company – in Vitebsk

Finland
Boliden Harjavalta
Boliden/Kemira - Kokkola
Kemira Oyj - Pori
Metsä Group - Äänekoski
Yara International – Siilinjärvi

Germany
Arsol Aromatics
Aurubis AG
BASF - Ludwigshafen
Berzelius - Stolberg
Chemie Kelheim Holding - Kelheim
DOMO Caproleuna - Leuna
Evonik Degussa - Worms
Grillo-Werke - Duisburg
Grillo-Werke - Frankfurt
Kelheim Fibres
Lanxess - Leverkusen
RAG AG
Sachtleben Chemie - Duisburg
TIB Chemicals - Mannheim
Tronox Pigments - Krefeld
Weser Metall - Nordenham
Xstrata Zinc – Nordenham

Lithuania
AB Lifosa locates in Kedainiai, which locates 50 km to north from Kaunas.
AB Mazeikiu Nafta

Poland
Fosfan - Szczecin

Fosfory - Gdansk
KGHM Polska - Glogow
KGHM Polska - Legnica
HCM S.A.
Petrochemia Blachownia
Zaklady Azotowe - Pulawy
Zaklady Boleslaw
ZCh Police

Russia

By the information from Eurochemgroup is one sulphuric acid producer "Phosphorit" (http://www.eurochemgroup.com/en/product/sulphuric-acid/)
Additional information about plant is on web page
http://www.sulphuric-acid.com/sulphuric-acid-on-the-web/acid%20plants/Phosphorit%20Industrial%20-%20Kingisepp.htm
The plant locates in Leningrad region, Kingisepp, which locates 20 km to east from Russian-Estonian border.

Company LLC "MetaChem" locates in Volkhov (Leningrad region), which is about 140 km east from St. Petersburg.

Sweden
Boliden - Ronnskar
Kemira Kemi - Helsingborg
Freudenberg Household Products

Appendix 3. Data for economic analyses, collected from countries participating present project

Belarus

Organisation: RUE "SPC of NAC of Belarus for Agriculture Mechanization"

Contact person: Nikolay Kapustsin

Cost item	Price, €, without VAT	Comments
Acid price € l^{-1}.	0,18	The price of 1000 l IBC tank. The wholesale price of Sulfur acid (94%) is 25 Euro per 1 ton.
Acid transportation cost to the farm € km^{-1}.	1,25	In Belarus it is possible to order specialized transport for transportation of acid. Cost of transportation of a capacity of 30 m3 is 250 euros without VAT for the total length of the route 200 km (round-trip);
Acid concentration, (e.g. 98%)	98	
Price of new empty IBC tank	61	Полиэтиленовый 1000 l IBC tank
Electricity price, € kWh^{-1}	0,08	With transfer cost and excise
Diesel fuel price for farms, € l^{-1}	0,53	
Diesel transportation cost to the farm € km^{-1}.	0,35	Автомобильным транспортом
Labour cost with taxes, € h^{-1}	2,4	Farm workers who operate acidification systems in the farm.
Cost of slurry incorporation with disc harrow, € ha^{-1}	8,1	Costs with own equipment.
N fertiliser price, € kg^{-1}	0,205	(Urea 46,2 % N) for 205 Euro per 1 ton

NS mineral fertiliser, € kg^{-1}	113	21N-24S without delivery
NP mineral fertiliser price, € kg^{-1}	0,6	NPK mineral fertilizer: N-16%, P-16%, K-16%
Fertiliser delivery cost to the farm, € t^{-1} km^{-1}	0,07	Truck with capacity 10 tonnes.
Mineral fertiliser handling costs in farm (storage, loading, transport to the field, spreading), € t^{-1}	30	With own equipment.
Liming material price, € t^{-1}	60	Dry dolomite flour ($CaCO_3$+$MgCO_3$)=93%
Liming material delivery to farm, € t^{-1} km^{-1}	0,07	Truck with capacity over 10 tonnes.
Lime handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), € t^{-1}	3	With own equipment.
Or liming service cost which includes three previous costs, € t^{-1}		
Rolled grass silage price, € t^{-1}	22	
Rolled grass silage handling costs (harvest, loading, transport from the field), € t^{-1}	8	
Barley price, € t^{-1}	140	
Wheat price, € t^{-1}	130	
Cereal yield handling costs (transport from the field, processing, loading and storage), € t^{-1}	13,2	Transport and processing costs.
Bank loan interest%, for agricultural equipment	9,5	

Denmark

Henning Lyngsø Foged suggested to use for Denmark same data what are collected from Sweden.

Acid price

Denmark	120-128		Included to acid price.	Delivery by truck
Denmark	136-157		Included to acid price.	IBC tanks, but price excluded the price of the IBC tanks

Estonia

Organisation: Estonian Crop research Institute

Contact person: Raivo Vettik, Kalvi Tamm

Cost item	**Price, €, without VAT**	**Comments**
Acid price € l^{-1}.	118-127	24 t portion.
Acid transportation cost to the farm € km^{-1}.	No need	Included to acid price.
Acid concentration, (e.g. 98%)	94-98%	
Price of new empty IBC tank	190	190 on plastic pallet and 175 on wood pallet
Electricity price, € kWh^{-1}	0,1	With transfer cost and excise
Diesel fuel price for farms, € l^{-1}	0,654	Cost is with fuel transportation to the farm
Diesel transportation cost to the farm € km^{-1}.		
Labour cost with taxes, € h^{-1}	7,4	Farm workers who operate acidification systems in the farm.
Cost of slurry incorporation with disc harrow, € ha^{-1}	31,9	Costs with own equipment.

N fertiliser price, € kg^{-1}	0,249	Ammonium nitrate, N 34%
NS mineral fertiliser, € kg^{-1}	0,209	AmmoniumSulphate 21N-24S /Lanxess, Germany/
NP mineral fertiliser price, € kg^{-1}	0,252	NP 33 - 3, N 33%, P 1,3%
Fertiliser delivery cost to the farm, € t^{-1} km^{-1}	No need	Included to fert price.
Mineral fertiliser handling costs in farm (storage, loading, transport to the field, spreading), € t^{-1}	27,3	The cost if amount of physical fertiliser is 350 kg / ha.
Liming material price, € t^{-1}	No need	
Liming material delivery to farm, € t^{-1} km^{-1}	No need	
Lime handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), € t^{-1}	No need	
Or liming service cost which includes three previous costs, € t^{-1}	16,7	ENEFIX fly ash 88 € ha, 3 t/ha, Jõgeva vald (Scandagra), Liming service with dolomite lime from Rakke lime producer - 16.7 € t-1 with 50 km transport
Rolled grass silage price, € t^{-1}	50	Supposedly, it is easier to find price for rolled grass silage.
Rolled grass silage handling costs (harvest, loading, transport from the field), € t^{-1}	15	
Barley price, € t^{-1}	130	
Wheat price, € t^{-1}	149	
Cereal yield handling costs (transport from the field, processing, loading and storage), € t^{-1}	30	

Bank loan interest%, for agricultural equipment	3	

Finland

Organisation: Association of ProAgria Centres

Contact person: Sari Peltonen

Cost item	**Price, €, without VAT**	**Comments**
Acid price € l^{-1}.	0,97	1300 kg container ≈ 710 l = 689 €
Acid transportation cost to the farm € km^{-1}.	70 €/tn	Transportation cost per ton acid
Acid concentration, (e.g. 98%)	93%	
Price of new empty IBC tank	210 €	Lower price if you order several (4-9 = 200 €, 10-15 = 185 €)
Electricity price, € kWh^{-1}	0,1011	With transfer cost and excise
Diesel fuel price for farms, € l^{-1}	0,77	**Includes the transportation**
Diesel transportation cost to the farm € km^{-1}.	-	
Labour cost with taxes, € h^{-1}	16	Farm workers who operate acidification systems in the farm.
Cost of slurry incorporation with disc harrow, € ha^{-1}	55	When the cost is 2,73 €/m^3 and the spreading amount is 20 m^3/ha
N fertiliser price, € kg^{-1}	0,323	Urea Plus, 46% N
NS mineral fertiliser, € kg^{-1}	0,245	21 N – 24 S
NP mineral fertiliser price, € kg^{-1}	0,47	(N12-P23-K0-S0) ammoniumN 11%, nitrateN1%

Fertiliser delivery cost to the farm, € t^{-1} km^{-1}	170	€/t regardless of the distance
Mineral fertiliser handling costs in farm (storage, loading, transport to the field, spreading), € t^{-1}	-	
Liming material price, € t^{-1}	-	
Liming material delivery to farm, € t^{-1} km^{-1}	-	
Lime handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), € t^{-1}	-	
Liming service cost which **includes three previous** costs, € t^{-1}	42	
Rolled grass silage price, € t^{-1}	120	Price of the solid matter
Rolled grass silage handling costs (harvest, loading, transport from the field), € t^{-1}	28	When the yield is 8000 kg/ha and the weight of one bale is 800 kg
Barley price, € t^{-1}	140	
Wheat price, € t^{-1}	165	
Cereal yield handling costs (transport from the field, processing, loading and storage), € t^{-1}	50	
Bank loan interest%, for agricultural equipment	2	

Germany

Organisation: Blunk GmbH

Contact person: Jonas Ostermann

Cost item	Price, €, without VAT	Comments
Acid price € l^{-1}.	0,48	IBC 1000 l
Acid transportation cost to the farm € km^{-1}.	0,90	appro. costs for transportation with a truck
Acid concentration, (e.g. 98%)	96%	
Price of new empty IBC tank	900 €	costs of one Varibox
Electricity price, € kWh^{-1}	-	With transfer cost and excise
Diesel fuel price for farms, € l^{-1}	0,90 € - 1,20 €	That is the range so far in germany
Diesel transportation cost to the farm € km^{-1}.	-	Tractors have enough storage for Diesel for 2 working days - no extra costs
Labour cost with taxes, € h^{-1}	27,50	Farm workers who operate acidification systems in the farm.
Cost of slurry incorporation with disc harrow, € ha^{-1}	15 - 30 € per ha	it depends on the working depth + appr. 2,90 € per cbm slurry
N fertiliser price, € kg^{-1}	0,213	CAN 27 % 13.12.2017
NS mineral fertiliser, € kg^{-1}	0,236	ASS (27%/ 13%) 13.12.2017
NP mineral fertiliser price, € kg^{-1}	0,319	DAP (18% N/46% P) 13.12.2017
Fertiliser delivery cost to the farm, € t^{-1} km^{-1}	0,90	appro. costs for transportation with a truck

Mineral fertiliser handling costs in farm (storage, loading, transport to the field, spreading), € t^{-1}	15 - 20	approx. It depends on the field - farm distance
Liming material price, € t^{-1}	31	
Liming material delivery to farm, € t^{-1} km^{-1}	1,1 € per km	
Lime handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), € t^{-1}	20 - 25	approx. It depends on the field - farm distance
Or liming service cost which includes three previous costs, € t^{-1}		If You send liming service cost, then three previous costs are not needed.
Rolled grass silage price, € t^{-1}	30	Supposedly, it is easier to find price for rolled grass silage.
Rolled grass silage handling costs (harvest, loading, transport from the field), € t^{-1}	10 € per to	+ 1,10 more per km
Barley price, € t^{-1}	140	13.12.2017
Wheat price, € t^{-1}	148	13.12.2017
Cereal yield handling costs (transport from the field, processing, loading and storage), € t^{-1}	10 - 15	approx. It depends on the field - farm distance
Bank loan interest%, for agricultural equipment	1,5 - 3,5 %	

Latvia

Organisation: Latvian Rural Advisory and Training Centre

Contact person: Santa Pavila

Cost item	Price, €, without VAT	Comments
Acid price € kg^{-1}.	0,15	The price of 1000 l IBC tank. Acid price for € l-1 - 0,27, 0.15 € kg-1
Acid transportation cost to the farm € km^{-1}.	1	
Acid concentration, (e.g. 98%)	98	
Price of new empty IBC tank	190	
Electricity price, € kWh^{-1}	0,11	With transfer cost and excise
Diesel fuel price for farms, € l^{-1}	0,63	
Diesel transportation cost to the farm € km^{-1}.	1	
Labour cost with taxes, € h^{-1}	5	Farm workers who operate acidification systems in the farm.
Cost of slurry incorporation with disc harrow, € ha^{-1}	22,92	Costs with own equipment. Service costs is 30.02 € ha-1
N fertiliser price, € kg^{-1}	0,23	Ammonium nitrate N - 34%
NS mineral fertiliser, € kg^{-1}	0,19	AmmoniumSulphate 21N-24S
NP mineral fertiliser price, € kg^{-1}	0,41	NP N - 33%, P - 3%
Fertiliser delivery cost to the farm, € t^{-1} km^{-1}	0,062	Truck with capacity 10 tonnes. Service costs 0.089 € t-1 km-1

Mineral fertiliser handling costs in farm (storage, loading, transport to the field, spreading), € t^{-1}	33,97	With own equipment.
Liming material price, € t^{-1}	48,38	Dry dolomite flour, Ca 20.3%, Mg 10.9%, packed in big bags 1 tonne.Price of dry limestone flour with Ca 38.4% in big bags is 64.03 € t-1. Raw dolomite sand - 6.5 € t-1 (without package).
Liming material delivery to farm, € t^{-1} km^{-1}	0,062	Truck with capacity over 10 tonnes. Service costs 0.089 € t-1 km-1
Lime handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), € t^{-1}	3,33	With own equipment.
Or liming service cost which includes three previous costs, € t^{-1}		If You send liming service cost, then three previous costs are not needed.
Rolled grass silage price, € t^{-1}	25	Price for rolled grass silage.
Rolled grass silage handling costs (harvest, loading, transport from the field), € t^{-1}	10,83	
Barley price, € t^{-1}	124	
Wheat price, € t^{-1}	158	
Cereal yield handling costs (transport from the field, processing, loading and storage), € t^{-1}	11,79	Transport and processing costs.
Bank loan interest%, for agricultural equipment	4-5	

Lithuania

Organisation: Lithuanian University of Health Science (Animal Science Institute)

Contact person: Artūras Šiukščius arturas.siukscius@lsmuni.lt

Cost item	Price, €, without VAT	Comments
Acid price € l^{-1}.	0,240	1000 l IBC tank (240 euro for 1000 l)
Acid transportation cost to the farm € km^{-1}.	1,20	
Acid concentration, (e.g. 98%)	96	
Price of new empty IBC tank	140	
Electricity price, € kWh^{-1}	0,090	With transfer cost and excise
Diesel fuel price for farms, € l^{-1}	0,524	With diesel fuel transportation
Diesel transportation cost to the farm € km^{-1}.	-----	
Labour cost with taxes, € h^{-1}	4,07	Farm workers who operate acidification systems in the farm.
Cost of slurry incorporation with disc harrow, € ha^{-1}	100	
N fertiliser price, € kg^{-1}	250	Please specify here the nutrient content of fertiliser **(saltpetre N-34,4 %) with transportation**
NS mineral fertiliser, € kg^{-1}	260	Please specify here the nutrient content of fertiliser (**NS 30-10) %with transportation**
NP mineral fertiliser price, € kg^{-1}	370	Please specify here the nutrient content of fertiliser (**NP 12-52) with transportation**
Fertiliser delivery cost to the farm, € $t^{-1}km^{-1}$	---	
Mineral fertiliser handling costs in farm (storage, loading, transport to the field, spreading), € t^{-1}	35	

Liming material price, € t^{-1}	130	**with transportation**
Liming material delivery to farm, € t^{-1} km^{-1}	---	
Lime handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), € t^{-1}	45	
Or liming service cost which includes three previous costs, € t^{-1}	175	If You send liming service cost, then three previous costs are not needed.
Rolled grass silage price, € t^{-1}	60	Supposedly, it is easier to find price for rolled grass silage.
Rolled grass silage handling costs (harvest, loading, transport from the field), € t^{-1}	20	
Barley price, € t^{-1}	130	
Wheat price, € t^{-1}	150	
Cereal yield handling costs (transport from the field, processing, loading and storage), € t^{-1}	25	
Bank loan interest%, for agricultural equipment	4	

Poland

Organisation: Agricultural Advisory Center

Contact person: Mateusz Sekowski

Cost item	**Price, €, without VAT**	**Comments**
Acid price € l^{-1}.	0,5	**25 l canister**
Acid transportation cost to the farm € km^{-1}.	0,72	
Acid concentration, (e.g. 98%)	95%	
Price of new empty IBC tank	120	
Electricity price, € kWh^{-1}	0,18	With transfer cost and excise
Diesel fuel price for farms, € l^{-1}	0,98	Farmer can reduce the disel fuel price (costs) by obtaining partially excise tax refund i.e. 20,5EUR/ha/year
Diesel transportation cost to the farm € km^{-1}.	The price of transport is included in the price of fuel (when buying large quantities)	
Labour cost with taxes, € h^{-1}	3,8	Farm workers who operate acidification systems in the farm.
Cost of slurry incorporation with disc harrow, € ha^{-1}	64,7	
N fertiliser price, € kg^{-1}	0,81	34% N **(pure N)**
NS mineral fertiliser, € kg^{-1}	0,23	24%S, 21%N

NP mineral fertiliser price, € kg^{-1}	1,3	8%N, 24%P
Fertiliser delivery cost to the farm, € t^{-1} km^{-1}	0,31-0,6	
Mineral fertiliser handling costs in farm (storage, loading, transport to the field, spreading), € t^{-1}	**27**	
Liming material price, € t^{-1}	24	
Liming material delivery to farm, € t^{-1} km^{-1}	0,31-1,0	
Lime handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), € t^{-1}	depends on farm	
Or liming service cost which includes three previous costs, € t^{-1}	32	8 without lime material
Rolled grass silage price, € t^{-1}	19	Supposedly, it is easier to find price for rolled grass silage.
Rolled grass silage handling costs (harvest, loading, transport from the field), € t^{-1}	12	
Barley price, € t^{-1}	144	
Wheat price, € t^{-1}	151	
Cereal yield handling costs (transport from the field, processing, loading and storage), € t^{-1}	depends on farm	
Bank loan interest%, for agricultural equipment	3-5 % (depending on the type of loan and bank)	

Russia

Organisation: NWRIAEO (North-West Research Institute of Agricultural Economics and Organizations)

Contact person: Mikhail Ponomarev

Cost item	Price, €, without VAT	Comments
Acid price € l^{-1}.	0,022	price from 1000 kg of technical acid. Improved acid = 0,27 (38 kg container)
Acid transportation cost to the farm € km^{-1}.	1	No examples of acid use in agricultural farms. The price is for transport of hazard cargo.
Acid concentration, (e.g. 98%)	98	
Price of new empty IBC tank	145	New IBC tank. Used tank = 85 EUR.
Electricity price, € kWh^{-1}	0,06	
Diesel fuel price for farms, € l^{-1}	0,36	With excise
Diesel transportation cost to the farm € km^{-1}.		included in the price
Labour cost with taxes, € h^{-1}	3,6	Farm workers who operate acidification systems in the farm.
Cost of slurry incorporation with disc harrow, € ha^{-1}	14	appoximate calculation; high variability
N fertiliser price, € kg^{-1}	0,5	converting to 100% content of N
NS mineral fertiliser, € kg^{-1}	0,14	NS 30:6
NP mineral fertiliser price, € kg^{-1}	0,32	NP 12:52
Fertiliser delivery cost to the farm, € t^{-1} km^{-1}	0,2	average transport price

Mineral fertiliser handling costs in farm (storage, loading, transport to the field, spreading), € t^{-1}	20	appoximate calculation; high variability
Liming material price, € t^{-1}	8,5	dolomitic lime in bulk
Liming material delivery to farm, € t^{-1} km^{-1}	0,2	average transport price
Lime handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), € t^{-1}	2	appoximate calculation; high variability
Or liming service cost which includes three previous costs, € t^{-1}		If You send liming service cost, then three previous costs are not needed.
Rolled grass silage price, € t^{-1}	60	There is almost no market of silage. Animal farms produce own silage.
Rolled grass silage handling costs (harvest, loading, transport from the field), € t^{-1}	10	appoximate calculation; high variability
Barley price, € t^{-1}	73	
Wheat price, € t^{-1}	97	
Cereal yield handling costs (transport from the field, processing, loading and storage), € t^{-1}	15	appoximate calculation; high variability
Bank loan interest%, for agricultural equipment	5-10	depends on: - machinery and equipment; - farm type; - subsidy

Sweden

Organisation:

Contact person: Line Strand

Cost item	Price, €, without VAT	Comments
Acid price € l^{-1}.	0,62 or 0,265	1000 l IBC tank or 25 t tank.
Acid transportation cost to the farm € km^{-1}.	already included in the price	
Acid concentration, (e.g. 98%)	98%	
Price of new empty IBC tank	220	
Electricity price, € kWh^{-1}	0,102	With transfer cost and excise
Diesel fuel price for farms, € l^{-1}	0,95	
Diesel transportation cost to the farm € km^{-1}.	0,015	3000 l trucks
Labour cost with taxes, € h^{-1}	24,94	Farm workers who operate acidification systems in the farm.
Cost of slurry incorporation with disc harrow, € ha^{-1}	50	45,6+70,85= 116,46 euro/h, capacity 2,4 ha/h including harrow, tractor, driver and fuel
N fertiliser price, € kg^{-1}	0,24	N34, not very common in Sweden, that is why it is more expensive than NS 27-4
NS mineral fertiliser, € kg^{-1}	0,22	NS 27-4
NP mineral fertiliser price, € kg^{-1}	0,39	(MAP) NP 12-23 Obs! plain P not P2O5
Fertiliser delivery cost to the farm, € t^{-1} km^{-1}	0,13	

Mineral fertiliser handling costs in farm (storage, loading, transport to the field, spreading), € t^{-1}	50	Depending on how far away the fields are, 5km distance in calculation
Liming material price, € t^{-1}		
Liming material delivery to farm, € t^{-1} km^{-1}		
Lime handling costs in farm (storage, loading, transport to the field, spreading or liming service cost), € t^{-1}		
Or liming service cost which includes three previous costs, € t^{-1}	28,62-30,67	
Rolled grass silage price, € t^{-1}	0,14	price in Euro/kg DM. It is uncommon in Sweden that you buy your silage without all the handling costs included.
Rolled grass silage handling costs (harvest, loading, transport from the field), € t^{-1}	0,14	price in Euro/kg DM for the farmer
Barley price, € t^{-1}	173 or 112	Barley for beerproduction or barley for fodder production
Wheat price, € t^{-1}	143 or 132	Wheat for bakery industry or wheat for fodder production
Cereal yield handling costs (transport from the field, processing, loading and storage), € t^{-1}	29,45	transport, drying, loading and storage
Bank loan interest%, for agricultural equipment	3 or 4	Machinery loan

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Baltic Slurry Acidification

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Summary of the project

Baltic Slurry Acidification is an agro-environmental project financed by Interreg Baltic Sea Region under the priority area Natural resources and specific objective Clear waters. The aim of the project is to reduce nitrogen losses from livestock production by promoting the use of slurry acidification techniques in the Baltic Sea Region and thus to mitigate eutrophication of the Baltic Sea.

Summary of the report

The economic aspects have a crucial role for the farmer's decision to choose one of acidification technologies or some other solution to minimise ammonia emission from slurry. The calculation models are composed within the project to compare different solutions. Present report gives overview about data and methods used in analysis models. The calculation results are presented for every country participating in the project. The report includes chapter about overall summary and conclusions of economic analyses and gives recommendations to improve cost-benefit of slurry acidification.