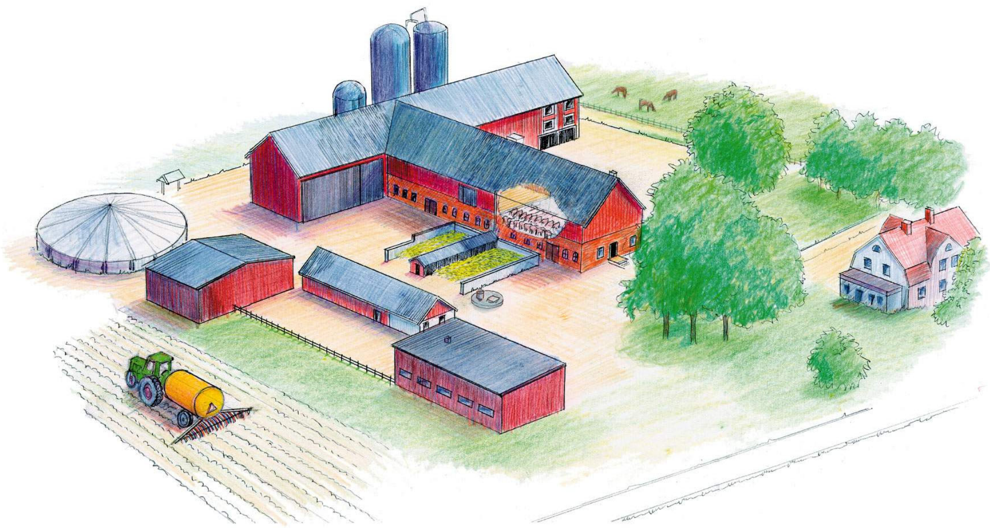
LIFE AMMONIA
Towards a sustainable milk production - reducing on-farm ammonia losses

LIFE 99ENV/S/000625

FINAL REPORT



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Department of Animal Environment and Health
Swedish University of Agricultural Sciences, P.O.Box 234, SE-532 23 Skara, Sweden
Tel: +46-511-67000 Fax: +46-511-67204
E-Mail: Jan.Hultgren@hmh.slu.se

Data Project	
Project location	Skara, Sweden
Project start date:	1/10/1999
Project end date:	30/9/2003
Total Project duration (in months)	48 months
Total budget	1,128,804 €
EC contribution:	542,668 €
(%) of total costs	50.00
(%) of eligible costs	48.07

Data Beneficiary	
Name Beneficiary	Swedish University of Agricultural Sciences Department of Animal Environment and Health
Contact person	Hultgren, Jan
Postal address	P.O. Box 234, SE-532 23 Skara, Sweden
Visit address	Gråbrödragatan 19, Skara
Telephone	Tel: +46-511-67000 , direct 67103
Fax:	Fax: +46-511-67204
E-mail	Jan.Hultgren@hmh.slu.se
Website	www.ammoniak.nu

EXECUTIVE SUMMARY

The purpose of the project was to demonstrate and evaluate a combination of techniques and methods for reduction of on-farm ammonia losses in milk production, without any substantial negative impact on animal health, plant production, environmental hygiene or on quality of end products, and to increase the knowledge in this area among Swedish and European farmers, extension workers, authorities and agricultural students.

An existing cow-barn on the research farm Brogården at the Swedish University of Agricultural Sciences in Skara, with 42 cows in long-stalls, solid manure handling and traditional husbandry methods was re-designed.

Three important areas for improvement were identified in the production chain, namely feeding, housing and storage-spreading of manure. Firstly, the feeding was adjusted more precisely to the level of production of the cows. The composition of the feed was modified and the protein content was lowered. Secondly, the housing system was changed into short-stalls with rubber slats, manure gutters with efficient urine separation, litter that lowered the pH level of the manure, lowered air temperature, cooling of manure gutters with incoming drinking water and a new efficient ventilation system. The exhaust air was filtered through a bio-filter, binding ammonia nitrogen to the filter material. Thirdly, slurry handling was introduced. The mixture of feaces, urine and cleaning water was stored in a roof-covered container. The slurry was spread in growing crops, using shallow injection or band spreading technique.

During the first year, reference measurements were carried out in the old barn. The amount of exhausted air and the ammonia concentration in the ventilation air were measured and the total emission from the barn was calculated to be 24 g ammonia/cow and day, on an average, corresponding to about 6% of the nitrogen excreted by the cows.

Losses during storage and spreading were also measured. Total losses from storage of both solid manure and urine during the period Nov. -99 – May -00, were 300 g ammonia nitrogen/day, in average. This corresponds to not more than 5 % losses in average, which could be considered as fairly low, but the registration period was concentrated to the winter period and the urine pit was covered with Leca™ pebbles. Losses during spreading of solid manure in autumn and spring were measured to be 9-21 % of applied total nitrogen. This corresponded to losses of about half of the amount, 50 %, of ammoniacal (plant available) nitrogen in solid manure. Losses at spreading of urine in the spring was measured to be 24% of the total ammoniacal nitrogen applied.

The cowshed was rebuilt during the period May – Sept. -00. A new feeding strategy with lower level of protein was introduced during the two winter periods 2000-01, 2001-02. The milk production increased from 30.6 before to 33.0 kg ECM/cow and day after the rebuilding. The feed intake increased during the same time from 18.5 to 20.4 kg dry matter/cow and day. The nitrogen efficiency, calculated on all cows including the dry period, increased from 27.8% before to 29.8% after the rebuilding.

The ammonia evaporation from the cowshed was registered during the two winter periods after rebuilding 2000-01 and 2001-02. During the first year after the rebuilding the ammonia evaporation from the cowshed was, in average, 27 g/hour, or 15 g/cow and day. This corresponded to a 40% reduction, compared with the year before rebuilding of the barn. During the second year after the rebuilding the ammonia emission was 31 g/hour or 18 g/cow and day, corresponding to a 25% reduction. The ammonia concentration in the air inside the barn was reduced from 8 ppm before to 3 ppm after the rebuilding.

The bio-filter worked very well. Only at some occasions was it possible to find traces of ammonia in the outgoing ventilation air after the bio-filter. The filter was in operation all the year, but in summertime the windows and doors were open in the cowshed, so when the cows where grazing only a part of the air from the barn passed through the bio-filter, which has been considered when calculating the total losses from the project.

The ammonia losses from the storage of slurry were reduces with about 95%, compared with the old system. The size of the storage made it possible to choose spreading time in such away that nitrogen was utilised better by the plants.

Spreading of slurry was done by injection and band spreading, methods that reduced ammonia losses considerably.

The total ammonia losses from Brogården decreased from 911 kg NH_3-N before to 307 kg NH_3-N after the rebuilding of the cowshed. The losses per kg milk were reduced from 2.3 to 0.7 gram.

The projects created a lot of interest and about 1,600 farmers, student, farm advisers, research people and others visited the cowshed. The project was presented at several national and international conferences, meetings and exhibitions. A website informed about the background of, the results and achievements in the project. At the end of the project period a brochure "Practical advices from the project Life Ammonia" was distributed to about 19,000 milk producers, advisers and others in the milk business.

The economic feasibility of the actions taken in the project has been discussed. Some actions, such as lower protein in the diet and spreading the slurry at the right time in the right way, are direct profitable for any farmer, but other actions must be carefully considered from case to case.

The project organisation worked very well and the accounting system at SLU was modified to facilitate budget follow-ups. The beneficiary, HMH, and the subcontractors all contributed as expected to the implementation of the project. The original budget for the project was not reached but there was an under spending of about 1.6 MSEK.

The achievements in the project are of great importance for the milk production in Sweden and can also by applied in parts of Europe and the Baltic states. Basic findings about ammonia evaporation can apply to new techniques in new cowsheds and feeding strategies can be implemented elsewhere.

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1 INTRODUCTION

1.1 Background and objectives

The atmosphere of Europe is polluted with nitrogen compounds from livestock (NH_3=ammonia), traffic (NO_X) and stationary sources (NO_X). The nitrogen emission from livestock is as large as the emission from traffic and stationary combustion sources together. Ammonia causes eutrophication, acidification and decrease in the biological variety.

International agreements have been reached within the frame of CLRTAP, the Gothenburg protocol was signed Dec 1, 1999 and within the European Union objectives have been formulated regarding the state of environment. Emission reduction goals for ammonia have been agreed by the member states in the National Emission Ceiling (NEC) Directive, 2001/81/EG.

In April 2001 the Swedish Government proposed a new policy containing 15 national environmental quality objectives (Proposition 2000/01:30). Out of these, "Only natural acidification", deals with ammonia emission from the agricultural sector. As a first step the aim is to reduce the ammonia emission from the agriculture with 7,300 tons up to year 2010, corresponding to a reduction of 13%. In Sweden 85% of the total ammonia emission origins from the agriculture, whereof 70% from cattle production. The main sources are from ventilation of the buildings, from storage of manure and at spreading of manure. One of the Swedish actions taken in order to reach the targets set by the Government is the organisation of an advisory service, free of charge for the farmers, which started 2001 in south Sweden (Greppa Näringen). Today almost 4,000 farmers have joined the program.

The purpose of the project Life-Ammonia was to demonstrate and evaluate a combination of techniques and methods for the reduction of on-farm ammonia losses in milk production and to increase the knowledge in this area among Swedish and European farmers, extension workers, authorities and agricultural students.

The methods used should be nationally profitable and possible for the individual farmer to implement and use. Furthermore, the measures taken should not have any substantial negative impact on animal health, plant production, and environmental hygiene or on the quality of end products.

The research farm Brogården at the Swedish University of Agriculture Sciences (SLU) was used for the project, an existing cowshed with 42 SRB (Swedish Red and White Breed) cows was rebuilt and the conditions prior to and after the rebuilding were studied. The impact at farm level of the changes inside the barn and in the manure handling system was also studied.

1.2 Expected results and environmental benefits

In the Inception Report, submitted in December 1999 the expected results were presented, se table 1. The figures given are at a production level of 10,000 kg ECM per cow and year.

Table 1. The expected result of the project in terms of less ammonia-nitrogen calculated as kg N/cow and year and g/kg ECM[1], as given in the Inception Report, Dec.1999

	Level on a typical farm like Brogården,	**Level after modification**	**Change**
Losses of nitrogen as ammonia (kg/cow and year)	56 kg	7 kg	87% reduction
Nitrogen in milk (g per/ECM[1])	6,6 g	0,7 g	89% reduction

[1] ECM = Energy Correlated Milk

All effects were related to calculated levels on an average Swedish dairy farm of the same size and level of mechanisation as Brogården. The results were expressed in terms of changes in these average levels as well as in actual levels at that time on Brogården.

The combination of actions taken in the project was expected to reduce ammonia emissions on the project farm by about 87%.

In Europe, the demonstrated methods would be most applicable in Finland, Norway, the Baltic States, Poland, Austria, Switzerland and parts of Germany, since milk production in these countries is based on grass-clover silage and housing during the winter.

1.3 Quantification of Objectives

1.3.1 Higher feed efficiency

The objective was to reduce the nitrogen in feed with 15-20% compared with typical farm levels, that at least 30% of the nitrogen (=protein) from feed should be incorporated in products and that there should be no negative effects on animal health, environmental hygiene, milk production or milk quality.

1.3.2 Reduced losses of ammonia to the air from the cowshed

The objective was to use the best cost-effective technique in stall design, manure removal, ventilation, and management to reduce the losses inside the barn by 80%, compared with typical Swedish farms. Methods should also be tested to recover ammonia from the air by using an outdoor bio-filter system.

1.3.3 Reduced losses of ammonia to the air during storage and spreading of manure

The objective was to build a slurry system and to use the most practical and cost-effective techniques during storage and spreading in order to reduce the losses by 88% per cow and year, compared to typical Swedish levels.

The objectives are summarised in Table 2.

Table 2. The nitrogen flow per cow and year, as stated in the Inception Report, Dec. 1999.

	Level on a farm like Brogården (kg of nitrogen)	**Level after modifications (kg of nitrogen)**	**Change**
Total in feed	173	143	15-20% reduction
In products	-43 (25% of N in feed)	-43 (30% of N in feed)	20% increase
Total from cow	**130**	**100**	
Lost to air in cow-house	-5 (4%)	-1 (1%)	75% reduction
Total to storage	**125**	**99**	
-in faeces	50		
-in urine	75		
Lost at storage			
-from faeces	-10 (20% of N in faeces)	-1 (1% of N in faeces)	93% reduction
-from urine	-8 (10% of N in urine)		
Total to spreading	**107**	**98**	
-in faeces	40		
-in urine	67		
Lost at spreading			
-from faeces	-20 (50% of N in faeces)	5 (5% of N in faeces)	83% reduction
-from urine	-13 (20% of N in urine)		
Total left to crops	**74** (57% of total N from cow)	**93** (93% of total N from cow)	63% increase

2 PROJECT MANAGEMENT AND PROCESS

2.1 Project phases

Because the project was a demonstration project it was based on available research results and already developed techniques, but the combination of these techniques in one place was unique. The project was mainly based on the knowledge of the beneficiary and the sub-contractors, who together possessed a broad knowledge in all the areas covered by the project. The project was divided in five main phases and each phase was divided into a number of tasks. During the entire life time of the project and also some months thereafter, the Dissemination task was carried out, informing about the project, its progress and achievements, through Swedish and international networks as well as on the Internet.

2.1.1 Situation analysis phase (Task 1-3)

This phase included collection of latest knowledge, techniques and methods within each field of the project i.e. feeding, housing systems and manure handling, reference measurements and definition of actions to be taken in the project.

Literature reviews, personal contacts and study tours were used to bring in the latest knowledge on the techniques and methods to be demonstrated from Sweden and other countries, e.g. the Netherlands, Denmark and Germany. The three analysis groups were responsible for this mapping of the state of the art.

Different techniques for decreasing ammonia losses were analysed and evaluated and calculations were made in order to define theoretically the combination of actions that would lead to a high efficiency of nitrogen and a low level of ammonia losses. This phase included the following tasks:

- Reference Measurements (Task 1)
- Analysis of Present Situation (Task 2)
- Definition of Actions (Task 3)

2.1.2 Re-designing phase (Task 4-5)

This phase included re-design of the farm facility for the housing, management and feeding of a herd of 42 dairy cows, in such a way that it would be possible to demonstrate techniques for the reduction of on-farm ammonia losses. This phase also included planning, purchase and contracting of building material and works, equipment and machinery.

The re-designing was planned according to the results of the evaluation of the different techniques studied during phase one. Other factors that influenced the planning were laws and regulations for cow facilities, the owner's demands and the physical limitations of the present facility. The Re-Designing Phase included:

- Planning of Re-Designing of Existing Cow Facility (Task 4)
- Re-Designing of Existing Cow Facility (Task 5)

2.1.3 Implementation phase (Task 6-12)

The combination of technologies and methods decided in the situation analysis phase was implemented. The level of ammonia in the barn, feed consumption, the emission during storage and spreading of slurry, the content of urea in milk, the impact of the actions on animal health and the efficiency in crop growing were measured continuously during the implementation period.

A nutrient/mineral balance on farm level was calculated to get the comprehensive view of the results of the actions taken. The tasks carried out during the implementation phase were:

- Feed Planning and Feeding (Task 6)
- Animal Health Surveillance (Task 7)

- Measurement of the Quantity and Quality of Milk (Task 8)
- Measurements of Ammonia in Exhaust Air (Task 9)
- Management in Cow-House (Task 10)
- Measurements of Ammonia Losses at Storage and Spreading of Manure (Task 11)
- Measurements of Nitrogen Efficiency in Plant Production (Task 12)

2.1.4 Evaluation phase (Task 13)

All documentation and results of the implementation phase were evaluated towards the project objectives. The evaluation also included a cost-benefit analysis and modelling of long-term effects on the environment. The details are further discussed in chapter "Technical Progress and Results" below.

2.1.5 Dissemination

During the life time of the project, information and dissemination of information was a main task. An Internet website, www.ammoniak.nu, was established in October 2000. The site had basic information about the ammonia problems; acidification and eutrophication, project description, project progress, actual achievements and publications. The website have had about 400-700 visitors per month during the period November 2000 to September 2003.

The rebuilt cowshed had a great number of visitors, around 1,600, from September 2000 to April 2003, when measurements ceased. The Project Manager and project members participated in a number of seminars and conferences, both in Sweden and abroad. For further details see chapter 6 below.

2.2 Beneficiary and Sub-contractors

Beneficiary was the Department of Animal Environment and Health (HMH), SLU, Skara and the sub-contractors were:

- Svenska Lantmännen ek. förening, Enköping
- Arla Foods AB, Göteborg
- The Swedish Institute of Agricultural and Environmental Engineering, Uppsala (JTI)
- The Department of Agricultural Biosystems and Technology, Alnarp (JBT)
- The Department of Agricultural Research Skara, Skara (JVSK)
- The Swedish Dairy Association, Uppsala (Svensk Mjölk)
- DeLaval AB, Tumba (former Alfa Laval Agri)
- Svenska Foder AB, Staffanstorp.

Contribution to the project was also received from the Swedish Farmers´ Foundation for Agricultural Research and the Municipality of Skara.

A formal collaboration agreement between the beneficiary and the sub-contractors was signed, covering legal and financial aspects during and after the project period.

2.3 Project Management

2.3.1 General aspects

The project organisation is illustrated by the Organisation Chart in Figure 1.

2.3.2 Management

The **Management Group** consisted of one representative for the beneficiary, one for each sub-contractor and the Project Manager. It met approximately twice a year to discuss strategic matters, reviewed the total budget and ensured the dissemination of the project.

The **Steering Committee** consisted of one representative each from Lantmännen, Arla Foods and HMH, and the Project Manager. It met two - four times a year to supervise the project and guide the Project Manager. This committee was responsible for the comprehensive view of the project and the co-ordination of the information from the analysis groups.

The **Project Manager** supervised and co-ordinated the implementation of the project with delegation from the Management Group and Steering Committee, and was responsible for the day-to-day operation of the project, the follow-up routines and the writing of reports. He was also responsible for parts of the dissemination task, e.g. taking care of visitors and keeping the web site updated.

2.3.3 Work Groups

Three **analysis groups** (Feeding, Housing and Manure) were responsible for their respective strategic areas, and gave input to the Steering Committee. The first task for each group was to put together a report, covering the present situation, the results of research and available techniques and methods in the area. The groups were then responsible for detail planning of the tests and measurements carried out within the project frame as well as evaluation and analyze of all data collected. The groups consisted of one representative from the following organizations and companies:

Feeding: JVSK (group leader), Svenska Foder, Svensk Mjölk, Lantmännen.

Housing: HMH (group leader), JBT, DeLaval, JTI

Manure: JTI (group leader), Lantmännen, JVSK.

The Information Group was responsible for the dissemination of the project (Dissemination Task). It consisted of one representative from Arla Foods /Svensk Mjölk (group leader), one from DeLaval and the Project Manager. The group also used external consultants and specialists for writing, layout, pictures etc.

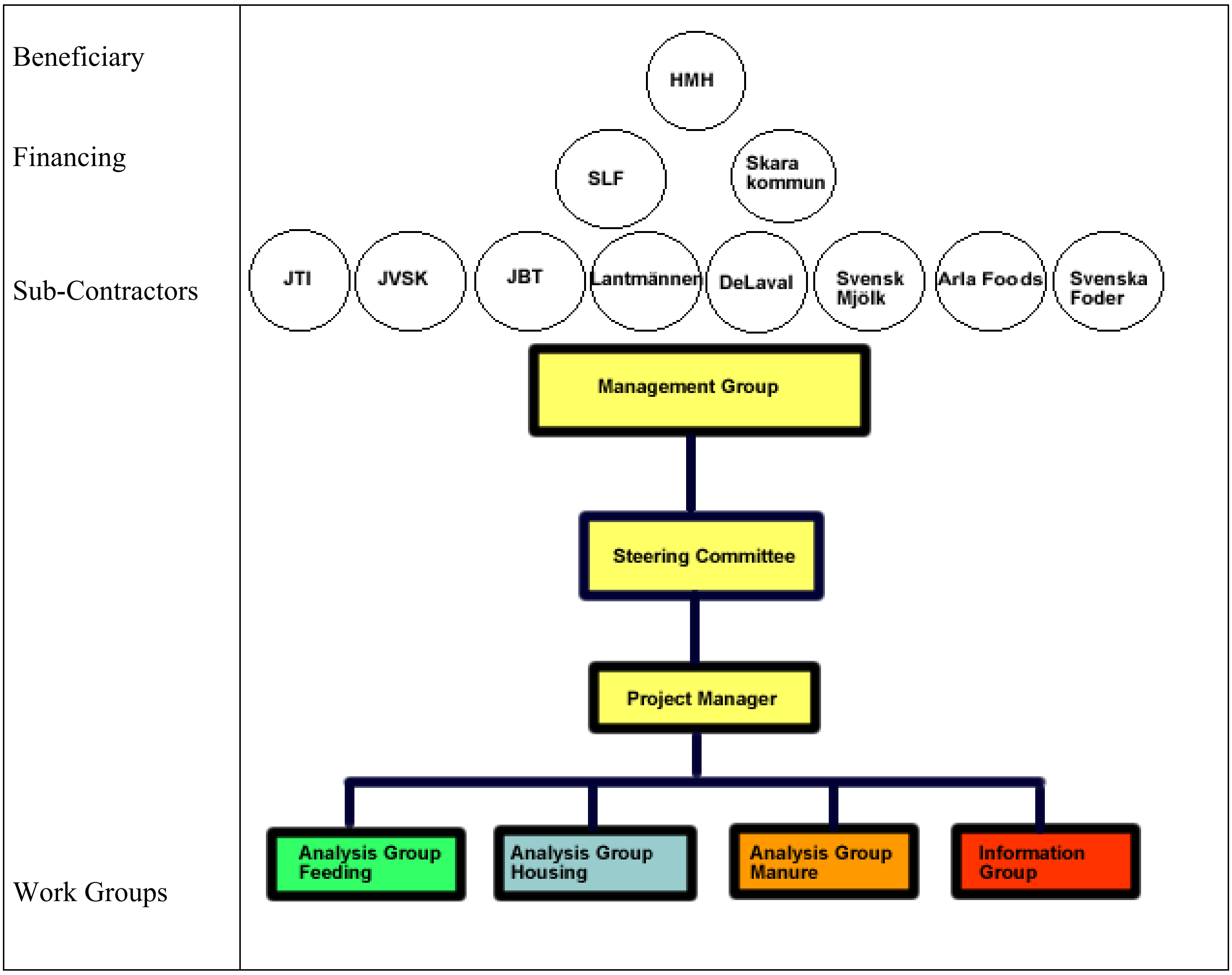

Figure 1. Project Organisation Chart

During the implementation of the project, some modifications and minor changes in names, ownership etc. occurred:

Swedish Environmental Research Institute Ltd, IVL, withdraw from the project due to incomplete funding of their contribution to the project. Their role in the project was taken over by JBT.

The two sub-contractors ODAL and LFU (Lantmännen Foderutveckling AB) were incorporated with Lantmännen due to reorganisation of the company group.

Alfa-Laval Agri AB changed name and became DeLaval AB.

JTI-Swedish Institute of Agricultural Engineering, changed their name to JTI- Swedish Institute of Agricultural and Environmental Engineering.

At the start of the project in October 1999, Jan Hultgren assumed the responsibility as provisional Project Manager. At the end of June 2000 Jan-Olof Sannö took over the responsibility as the permanent Project Manager.

As agreed upon with the LIFE Desk Manager in Jan. 2000 and indicated in Progress Report no. 2 in October 2000, the Project Manager was employed by ODAL/Lantmännen from Jun. -00 to Aug. -01 for practical reasons.

During the entire project period, Oct. 1999 to the end of Sep. 2003, the Management Group and the Steering Committee had a number of formal meetings as indicated in the schedule below. All group leaders and the Project Manager had a co-ordination meeting in Jun. 2000. The Steering Committee and all members in the workgroups held a co-ordination seminar in Jan. 2001. The results from all investigations and measurements were presented at a seminar in Skara, 24/9 2003. In connection with this seminar a separate project evaluation meeting was held, with participants from almost all partners and analyse groups.

	-99	**2000**				**2001**				**2002**				**2003**		
	Q4	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
Management Group	1	1	2 2	3	4 3	1	2 4	3 5	4	1	2 6	3 7	4 8	1	2 9	3 10
Steering Committee		xx	x	x	x	x	x	x			x	x	x	x		x
Co-ordination Meetings			x													x

The Project Manager also participated in meetings within the workgroups as well as in the building meetings during the reconstruction of the cow barn.

The organisation described functioned well, despite the great number of sub-contractors in the project. The three Analysis Groups carried out planned work and presented their reports from Task 1 with the Interim Report and from Task 2 with Progress Report no. 1. All earlier submitted reports from the Analysis Groups are also included in the present report. The co-ordination seminar in January 2001 informed all people involved in the project, provided a better understanding, gave a platform for the coming work and focused on the goals of the project.

Detailed plans for all project tasks were prepared by the responsible Analysis Groups and a detailed project budget was prepared by the Project Management in July 2000. The accounting system at the SLU was expanded with a project oriented accounting plan, based on the actual tasks in the project and the budget lines from the Commission, so in total 144 new accounts were set up. This system together with a periodic budget plan served as an efficient tool for the budget follow-ups every three months.

2.3.4 Auditing

Öhrlings PriceWaterhouseCoopers AB, Box 223, Torggatan 15 A, 54125 Skövde (Org. nr: 556029-6740) was appointed auditor in the project. The company is well established in this branch and has a worldwide network of consultants within economic consulting. In accordance with guidelines from the SLU auditing took place every 6 months. The auditor primary reported to the central administration at SLU. The final audition was carried out at the end of the project period according the guidelines from the Commission.

3 TECHNICAL PROGRESS AND RESULTS

The research farm Brogården had 93 ha of arable land and 70 ha of forest. The cowshed was built in 1920 and rebuilt several times, the latest in 1973. The herd consisted of 42 SRB cows and young stock up to 12 months of age. The cows were housed in a traditional system with long-stalls and solid manure handling. The herd had been used for experiments and trials at the Department for Animal Environment and Health since 1948, with focus on production diseases related to feeding and metabolism.

Three important areas for reducing ammonia losses in the production chain were identified: feeding, housing and handling of manure. Firstly, the feeding was adjusted more precisely to the level of production of the cows. The protein content was lowered and the composition of the feed ration was modified. Secondly, the housing and management system was changed into short-stalls, gutters with efficient separation of the urine, litter that lowers the pH level of the manure, lowered air temperature, and a new ventilation system that minimized the air velocities over surfaces exposed to manure. The exhaust air was filtered through a bio-filter, binding ammonia in the air to the filter material. Thirdly, slurry handling was introduced. It was stored in a roof-covered container. Slurry was spread in growing crops, using band spreading technique and on grassland, using shallow injection technique.

3.1 Reference Measurements (Task 1)

Reference measurements and recordings of ammonia losses from the cowbarn, from stores for manure and urine and at spreading of manure and urine, chemical composition of feedstuffs, milk yield and milk composition and animal health were carried out according to the plan during the Reference Period, November 1999 to May 2000. Basically nothing changed in the cowshed; the feeding regime was kept as before, management routines were the same as before etc. The only modification carried out was the installation of a fan in the cross channel for manure, in order to improve the real bad climate inside the barn, This, however, had no effect on the total ammonia emission from the barn, see below.

3.1.1 Animal feeding and milking performance

During the Reference Period the forage consisted of silage and hay produced on the farm. Grain was a mixture of 30% wheat and 70% oat, grown on the farm. Protein concentrate was purchased. Table 3 shows the diet composition, feed effiencies and dietary composition for the three production groups. Table 4 shows milk yield and milk composition in the different production groups. Of particular interest in this overview is the increase of nitrogen efficiency in milk production from 28 to 32 % when the milk yield by the cows increased. The nitrogen efficiency is calculated as the amount of nitrogen (based on the protein level) in milk produced divided by the amount of nitrogen (based on the protein content) in the feed consumed by the cow.

Table 3. Feed consumption, feed efficiency and dietary composition for lactating cows (excluding dry periods) during reference period (99/00)

Feed / cow and day; diet composition	Reference period ECM (kg/cow and day)			
	>35	25-35	<25	Average
No. of cows	8.0	21.0	6.3	35.3
Forages[1], kg DM	8.6	8.5	8.6	8.5
Grain mixture[2] ,kg DM	6.0	4.6	3.4	4.7
Prot. conc.[3], kg DM	6.6	5.3	3.6	5.3
Dry sugar-beet pulp, kg DM	0.0	0.0	0.0	0.0
Concentrates, kg DM	12.6	9.9	7.0	10.0
Total feed, kg DM	21.2	18.4	15.7	18.5
Forages, % of total feed	41	46	55	46
Feedeff.[4], kg DM / kg ECM	0.54	0.62	0.70	0.61
Feed eff.[4]., MJ / kg ECM	6.81	7.74	8.55	7.56
Crude protein, g/kg DM	170	168	163	168
AAT[5], g/MJ	7.7	7.7	7.5	7.7
PBV[6], g/day	362	340	288	336
Rum. degr. prot.[7], g/kg DM	109	110	111	110
Rum. undgr. prot[8], g/kg DM	61	58	52	58
Energy[9], MJ/kg DM	12.6	12.5	12.2	12.5
NDF, g/kg DM	375	394	424	395
EFD[10], % of NDF	50	50	51	50
Starch, g/kg DM	172	151	126	151

[1]Forages contained grass-clover silage at ad libitum intake and hay at 2 kg / cow and day.
[2]Grain mixture contained 70% oat and 30% wheat.
[3]Prot. conc.=protein concentrate (Unik from Lantmännen).
[4]Feed eff.=feed efficiency, kg DM of feed /kg ECM (energy corrected milk) and megajoule (MJ) / kg ECM.
[5]AAT=amino acids absorbed in small intestine.
[6]PBV= balance between ruminally degradable protein and undegradable proteins.
[7] Rum. degr. prot. =amount of ruminally degradable protein.
[8]Rum. undgr. prot.=rumen undegradable proteins.
[9]Metabolisable energy.
[10]EFD= effective fibre degradation, proportion of NDF that is ruminally degradable.

Table 4. Milk yield and milk composition in different production groups, during the reference period (Jan. – May 00

Production Group	**> 35 kg ECM**	**25-35 kg ECM**	**0-25 kg ECM**
Production trait	Average	Average	Average
Lactation no.	2.6	1.7	1.6
Lactation stage, days	116	148	252
ECM, kg/day	39.2	29.7	22.4
Milk, kg/day	38.3	29.8	20.9
Fat, %	4.4	4.2	4.6
Protein, %	3.2	3.2	3.5
Fat, kg/day	1.7	1.2	1.0
Protein, kg/day	1.2	1.0	0.7
Urea, mmol/l	5.1	5.0	4.6
Nitrogen efficiency, %	32.4	30.7	28.0

3.1.2 Ammonia emission from cowshed

The measurements during the Reference period covered the time from November 25, 1999 to May 15, 2000. A number of parameters were measured in the barn. In general the indoor climate was poor, with a low ventilation rate, occasionally high concentrations of ammonia and air leakage into the barn via the dung culvert.

The ammonia concentration in the exhaust air was measured with an infrared spectrophotometer, and the ventilation rate through the cowshed was continuously measured with an impeller in the exhaust duct. A data logger recorded the ammonia concentration and ventilation rate, as well as the carbon dioxide concentration, outside and inside air temperatures and air humidity. The average ammonia emission from the cowshed was 42 g/h corresponding to 24 g/cow and day, which was equivalent to a nitrogen loss of about. 7%. During the same period, the average ammonia concentration in the cowshed was 7.9 p.p.m. The results of the measurements of ammonia emission and climate parameters are summarized in Table 5.

Table 5. The results of the measurements of ammonia emission, ammonia concentration, ventilation rate, carbon dioxide concentration, inside and outside temperature and inside and outside relative humidity during the reference period. Values of 110 daily averages.

Parameter	Average	Standard deviation	Max - Min
Ammonia emission, g/h	42	9.2	71 - 15
Ammonia emission, g/cow and day	24	4.6	37 - 13
Ammonia concentration, p.p.m.	7.9	3.2	13.9 - 2.1
Ventilation rate, m^3/cow and h	152	29	218- 87
Carbon dioxide concentration, p.p.m.	2,103	424	3,592 - 1,435
Inside air temperature, ^{o}C	16.5	0.7	19.3 - 14.9
Outside air temperature, ^{o}C	1.3	3.7	9.0 - -10.1
Inside air humidity, %	62	11	98 - 33
Outside air humidity, %	84	10	98 - 54

The ammonia concentration in the cowshed was reduced when an exhaust fan connected to the manure channel was used during the last two months of the reference period. The mean ammonia concentration in the barn was reduced to 4.2 p.p.m. without any increase of the total ammonia emission (24 g/cow and day).

The variation in ammonia emission, ammonia concentration and ventilation rate during a day is illustrated by Figures 2 and 3. Two maxima of ammonia emission are seen, one around 8 a.m. and the other around 5 p.m., at manure removal from the barn.

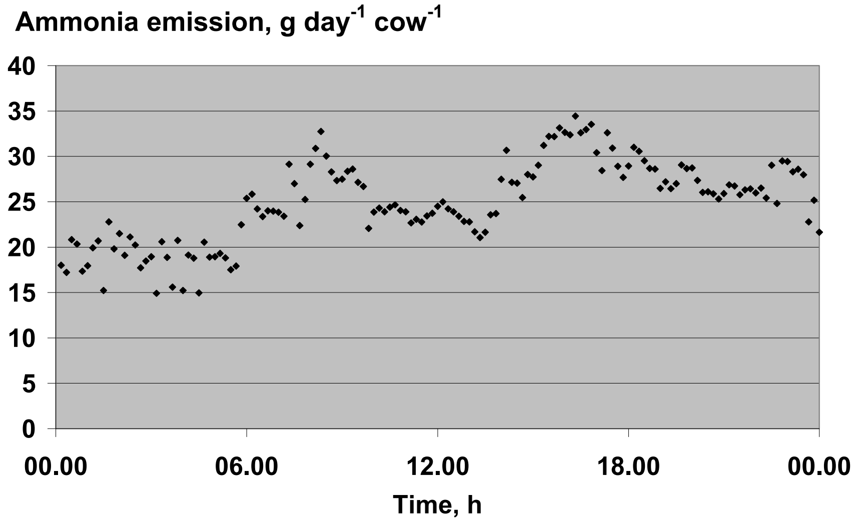

Figure 2. Ammonia emission during one day (February 18, 2000) of the reference period.

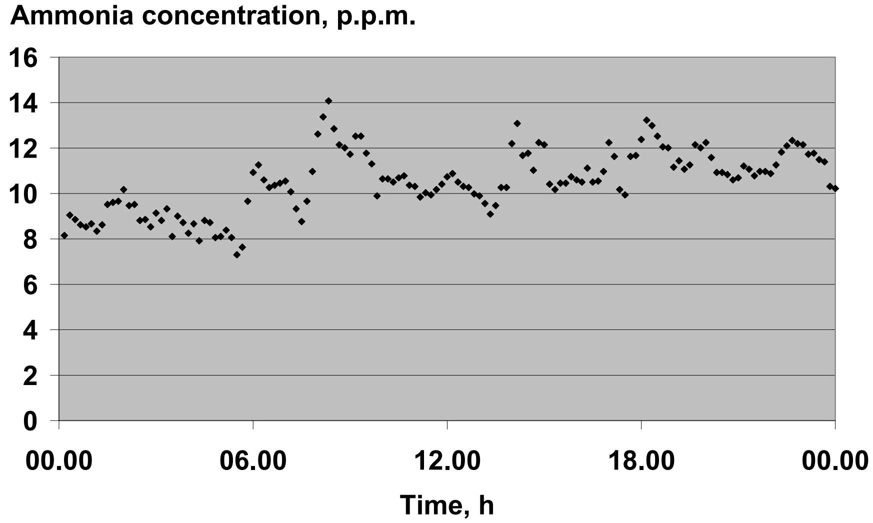

Figure 3. Ammonia concentration in exhaust air during one day (February 18, 2000) of the reference period.

The ventilation rate followed the step-by-step fan speed controller regulating the ventilation in the cowshed. During most of the day, the ventilation rate was around 5,700 m^3/h.

3.1.3 Storing of manure

The average ammonia losses during one year from a solid manure storage and a urine pit like the ones at Brogården are generally estimated to be 10-15 %. This estimate is partly based on the fact that the solid manure at Brogården had characteristics of semi-solid manure. Further, the urine container had a layer of floating Leca™ pebbles. Both circumstances reduced the ammonia evaporation rate. The ammonia emission from the both storages was measured with fluxsampler. Based on the measurements during the winter period, Nov. 1999 – May 2000 the average daily emission rates for the period were calculated, se figure 4. From the manure stored on the pad, the average loss was 220 g NH_3-N /day. The corresponding figure for the urine pit was 80 g NH_3-N/day. The total average loss of 300 g NH_3-N/day corresponded to not more than 5 % loss.

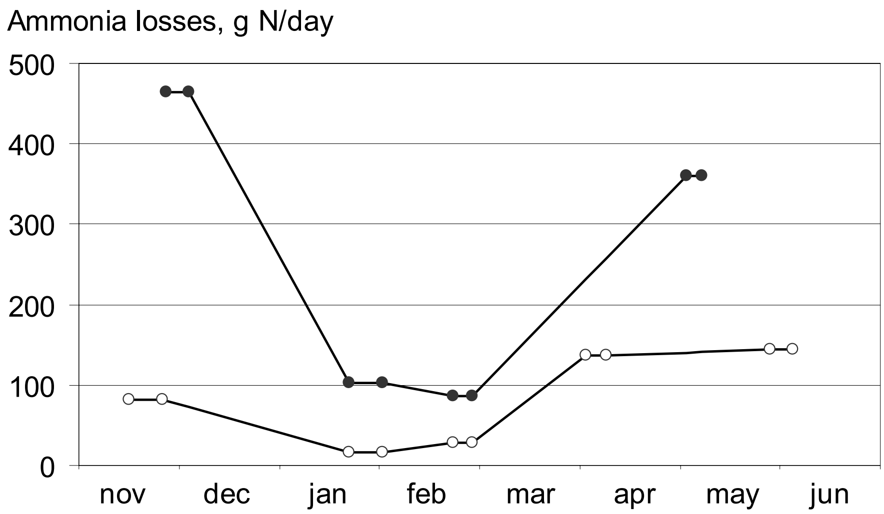

Figure 4. Ammonia emission during storage of solid manure on a manure pad , top line, and urine in a urine pit, bottom line, at Brogården , November 1999 – May 2000.

The rather low figures can be explained by the fact that the measuring period was limited to the part of the year dominated by winter climate. The average emission rates were estimated to be higher if measurements for a complete year were available.

3.1.4 Spreading of manure

The spreading of solid manure took place in autumn 1999 and in spring 2000, see table 6. The autumn spreading was done in a traditional way, with a broadcast spreader followed by ploughing the next day (see figure 5).

Figure 5. Spreading solid manure in the autumn 1999

Application rate was 28 tonnes per hectare and the losses were measured to be 9 % of the total nitrogen applied, corresponding to 48 % of the ammoniacal (plant available) nitrogen in the manure. The spreading on bare soil in early spring is also a traditional way for manure application. Losses were similar to the losses in the autumn, 14 and 43 % respectively, see table 7. Spreading on ley in April should be seen as a test in order to demonstrate spreading to an established crop at the start of the growing period, with a non-suitable manure type. Spreading to this crop in spring would be favourable in many aspects, if it could be done in a proper way. However, traditional solid manure spreading often leads to uneven spreading patterns, not allowing any incorporation into the soil and can easily cause severe soil compaction and crop damage. This spreading test also showed higher losses, 21 and 53 % respectively, than the other mentioned above. Considering ammonia, it has been found in earlier studies that losses are expected to be even higher if spreading is made in early summer, after the first cut of grass.

Table 6. Spreading periods with ammonia measurements during the first year of the project

Spreading period	Type of manure	Field characteristics	Incorporation method
10 Nov 1999	Solid manure	Stubble	Ploughing (1 day after spreading)
29 Mar 2000	Solid manure	Bare soil	Harrowing (at spring tillage)
11 Apr 2000	Solid manure	Ley	None
11 Apr 2000	Urine	Ley	None

Table 7. Overview of results from field studies on solid manure spreading and urine spreading at Brogården farm

	Solid manure, Nov 1999	Solid manure, Mar 2000	Solid manure, Apr 2000	Urine, Apr 2000
Field characteristics	Stubble	Bare soil	Ley	Ley
Mean application rate, tonnes/ha	28	30	15	24
Applied total nitrogen, kg N/hectare	117	183	76	60
Applied TAN, kg N/hectare	23	61	30	55
Ammonia emission,				
kg N/hectare	11	26	16	14
% of applied total nitrogen	9	14	21	22
% of applied TAN	48	43	53	24

When comparing ammonia losses from spreading of solid manure and urine, it should be held in mind that out of total nitrogen content in solid manure only 20-40 % is ammoniacal (plant available), whereas the corresponding figure for urine is 90 %. Despite this fact, the loss of ammonia is lower when spreading urine than solid manure. In the present study, almost twice as much TAN (total ammoniacal nitrogen) was applied per hectare in urine compared with solid manure in April. However, the relative loss from urine was less than half of the loss from solid manure. One important factor is that the fluid liquid can penetrate into the soil rather quick, while the solid manure nitrogen remains on the soil surface exposed for evaporation.

3.1.5 Mineral balance

Based on the collected data from the reference year, an attempt has been made to calculate the actual mineral balance and nitrogen efficiency on Brogården, see table 8.

Table 8. Mineral balance and nitrogen efficiency on Brogården during 1997, 1998 and 1999

	1997	**1998**	**1999**
Cows/ha	0.42	0.41	0.41
Delivered milk/cow	8,508	9,238	9,367
Delivered milk/ha	3,531	3,784	4,089
Input, kg N/ha			
Feed	25	26	37
Mineral fertilizer	130	123	112
N-fixating	15	6	12
N from the atmosphere	5	5	5
Others	7	8	5
Total input	**182**	**168**	**171**
Output, kg N/ha			
Milk	19	20	22
Meat	4	3	3
Crop	78	60	71
Total output, kg N/ha	**101**	**85**	**75**
Surplus kg N/ha	81	85	75
Output/input	55%	49%	56%

Cereals accounted for 75% out of the total nitrogen output, indicating that Brogården´s main product was wheat, not milk. The balance for phosphorus showed a deficit of 5 kg/ha and year and the corresponding balance for potassium also indicated a deficit of 5-10 kg/ ha and year.

The nitrogen surplus at Brogården was 75 –85 kg/ha and year was regarded as normal in this part of Sweden. On farms with milk production in the south of Sweden, the surplus varies from 84 to 210 kg N/ha. The degree of utilization varies from 0.18 to 0.57. The output/input ratio indicates how well purchased nitrogen is utilised on the farm and turned into crops, milk and/or meat.

The full reports from the Reference period, worked out by the Analyse groups are attached to this report, Appendix C.

3.2 Analysis of Present Situation (Task 2)

The state of the art regarding research and actions taken in order to decrease the ammonia losses in Europe was analysed by the Feeding, Housing and Manure Groups, resulting in three reports in English (submitted with Progress Report no 1 and to this report, Appendix B). These reports formed a package of background information to milk producers, students and advisors, published on the projects homepage.

3.3 Definition of Actions (Task 3)

Based on the efforts of the work groups and the output from Task 2, the Steering Committee defined further actions in the project continuously. The Steering Committee considered this task to be part of the overall project management and no special report was produced from this task.

3.4 Planning of Re-Designing of Existing Cow Facility (Task 4)

The planning of the re-design of the existing cow facility at the project site was carried out by means of discussions within the Housing Group, together with representatives from SLU and a technical consultant from the Swedish Federation of Rural Economy and Agricultural Societies. Five formal planning meetings were held from November 1999 through February 2000. Study visits to three other dairy facilities (in Falköping, Alnarp and Uppsala) were made in February 2000. Different pieces of equipment, installation details and management routines were tested in the cow-barn during January 1999 –March 2000, to form a basis for decisions regarding the final design. The tests were performed in such a way not to disturb the reference measurements. The re-designing of the dairy facility was finished in March 2000. The output from the task was summarised in a general layout of the new barn, see Appendix D.

3.5 Re-Designing of Existing Cow Facility (Task 5)

An official tender was sent out in April 2000 and a contract was signed on May 3, 2000 with Calles Bygg AB, a local building contractor, well established in the region as contractor for both public and agricultural buildings. The cows at Brogården were moved to a neighbouring farm on May 15 and the demolishing of the existing cow facilities could start. All equipment, stalling and flooring were removed and new channels for the slurry handling, cow stands and floors were built. The new stalls were 2.20 m wide and 1.81 long, equipped with 31 cm rubber slats in the rear part of the stall. (Figure 7). Special attention was given to the design of the new dung channels with efficient urine drainage and cooling of the bottom of the gutters with incoming drinking water in plastic pipes. See figure 6.

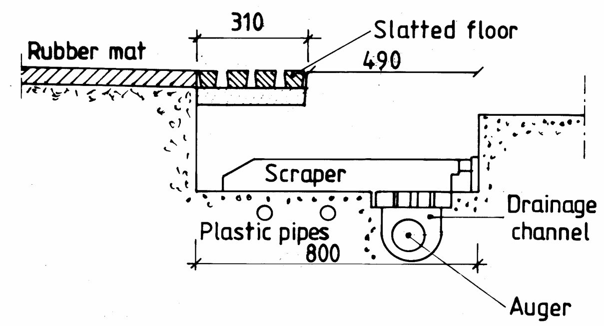

Figure 6. Gutters with urine drainage and cooling

Excavation for the pump pit and manure store on the site was carried out. Installation of new equipment (milking, manure handling, stalling etc), see figure 5, could start according to the plan Sept. 1. The cows were moved back to the rebuilt barn on Sept. 21.

Figure 7. Interior from the new cowshed.

The new facilities were officially inaugurated on Dec. 6, 2000 by Göran Dalin, Dean of the Faculty of Veterinary Medicine at SLU. A total of approximately 60 persons, representing the beneficiary and sub-contractors in the projects, as well as representatives for Skara municipality, were present. Later during the day, farmers and other people working in the agricultural sector were invited to “open house” in the new barn.

In mid December the bio-filter, se figure 8, was activated and it was then in operation until the end of the project period. The filter material was changed from the original idea of a soil-based material to microbiologically prepared chopped wood in combination with straw. A major point was to keep the filter bed moisty by using an irrigation system, located in the bottom of the filter so that the air from the barn brought the moisture upwards in the filter.

Figure 8. Bio-filter with chopped wood and straw.

3.6 Feed Planning and Feeding (Task 6)

During the entire harvest seasons 2000, 2001 and 2002, the total amounts of hay, silage and grain were registered from each field. Samples were taken from the harvests and later analysed for nutrient content. Based on these analyses, the Feeding Group worked out a detailed plan for feeding the cows during the coming winter season. The new feed ration had a lower level of protein, by 10 gram crude protein/kg dry matter, than before the rebuilding of the barn and the diet was well balanced in respect of protein, energy, starch and fibre contents. Feeding according to the new plan started Dec. 1, 2000 and was then adjusted monthly, according to the official recording of milk production. The dry-matter content of the silage was checked weekly in order to closely monitor the feed intake of the cows. The trial continued up to end of April 2001, when the cows were let out on pasture. All feed were weighed individually and the feed consumed for each cow was adjusted by the end of each 30 day period. The same routines were used in the season 2001-2002 and the result from these two years are summarised in Table 9.

Table 9. Feed consumption, feed efficiency and dietary composition for lactating cows (excluding dry periods) as an average over the first two years (00/01, 01/02) after the rebuilding of the cowshed at Brogården.

Feed / cow and day; diet composition	Average of year 1 and 2 after the rebuilding of the cowshed. ECM (kg/cow and day)			
	>35	25-35	<25	Average
No. of cows	13.2	15.7	5.8	34.7
Forages[1], kg DM	8.2	8.0	8.9	8.2
Grain mixture[2] ,kg DM	7.1	6.1	5.1	6.3
Prot. conc.[3], kg DM	5.9	4.5	2.4	4.7
Dry sugar-beet pulp, kg DM	1.8	1.1	0.0	1.2
Concentrates, kg DM	14.8	11.7	7.5	12.2
Total feed, kg DM	23.0	19.7	16.4	20.4
Forages, % of total feed	36	41	54	40
Feed eff.[4], kg DM / kg ECM	0.57	0.65	0.78	0.63
Feed eff.[4], MJ / kg ECM	7.13	8.00	9.21	7.76
Crude protein, g/kg DM	163	159	154	160
AAT[5], g/MJ	8.0	7.8	7.3	7.8
PBV[6], g/day	185	170	175	178
Rum. degr. prot[7], g/kg DM	103	105	109	104
Rum. undgr. prot[8], g/kg DM	60	54	45	55
Energy[9], MJ/kg DM	12.4	12.3	11.8	12.3
NDF, g/kg DM	352	366	398	366
EFD[10], % of NDF	51	50	50	50
Starch, g/kg DM	202	201	198	201

[1]Forages contained grass-clover silage at ad libitum intake and hay at 2 kg / cow and day.
[2]Grain mixture contained 40% wheat, 40% barley and 20% oat during the first two experimental years.
[3]Prot. conc.=protein concentrate (Unik from Lantmännen).
[4]Feed eff.=feed efficiency, kg DM of feed /kg ECM (energy corrected milk) and mega joule (MJ) / kg ECM.
[5]AAT=amino acids absorbed in small intestine.
[6]PBV= balance between ruminally degradable protein and microbial protein synthesis.
[7]Rum. degr. prot. =amount of ruminally degradable protein.
[8]Rum. undgr. prot.=rumen undegradable proteins.
[9]Metabolisable energy.
[10]EFD= effective fibre degradation, proportion of NDF that is ruminally degradable

The importance of chemical composition and hygienic quality of the feedstuffs in the ration, and thereby on nitrogen efficiency, became clear over the years in the project. Due to periods with rainy weather at the time of optimal harvest, and also other practical limitations, crude protein concentration (CP%) became higher than planned in the forage. In addition, hygienic quality in the silage was not good enough during on of the winter feeding periods. Considering that we had no alternative roughage available, rolled grain was the only economical feedstuff with which we could keep the low CP% in the diet. Therefore, we ended up in a situation were we had to offer the cows less silage and more grain than optimal. Because of the high CP% in the silage, dietary CP% became higher than desired for mid and late lactation cows.

The cows ate, on average, 1.9 kg DM (dry matter) more and produced 1.8 kg more energy corrected milk (ECM) than before the rebuilding of the cowshed, see table 10.

Table 10. Average milk yield and milk composition according to monthly test-day recordings and weekly analyses of delivered tank milk before (1999-2000) and after rebuilding (2000-01 and 2001-02) of the cowshed at Brogården.

	Before	After, 2000-01	After, 2001-02
ECM[1], kg/day	30.6	31.7	33.0
Mjölk[1], kg/day	30.1	31.1	31.9
Fatt[1], %	4.3	4.3	4.4
Protein[1], %	3.3	3.3	3.4
Fat[1], kg/day	1.3	1.3	1.4
Protein[1], kg/dygn	1.0	1.0	1.1
Urea[1], mmol/l	5.0	5.1	4.2
Whey protein[2], %	0.95	0.91	0.95
Casein[2], %	2.24	2.31	2.39
Freezing point[2], ºC	-0.532	-0.527	-0.526
Fat index[2]	0.02	-0.03	-0.06
Smell-/Taste remarks[2]	None	None	None

[1] According to monthly test-day recording.
[2] According to milk tank analyses.

3.6.1.1 Nitrogen efficiency

The nitrogen efficiency (amount of N in milk produced/amount of N in feed consumed) improved with increased milk production. Based on 588 observations from the period before rebuilding and the two periods after the rebuilding, the nitrogen efficiency increased by 0.29 percentage units for each kg of milk produced, see figure 9. This seems to be a rather straight correlation but it should be carefully used. There are a number of other factors influencing the N-efficiency, such as protein degradability and feed composition.

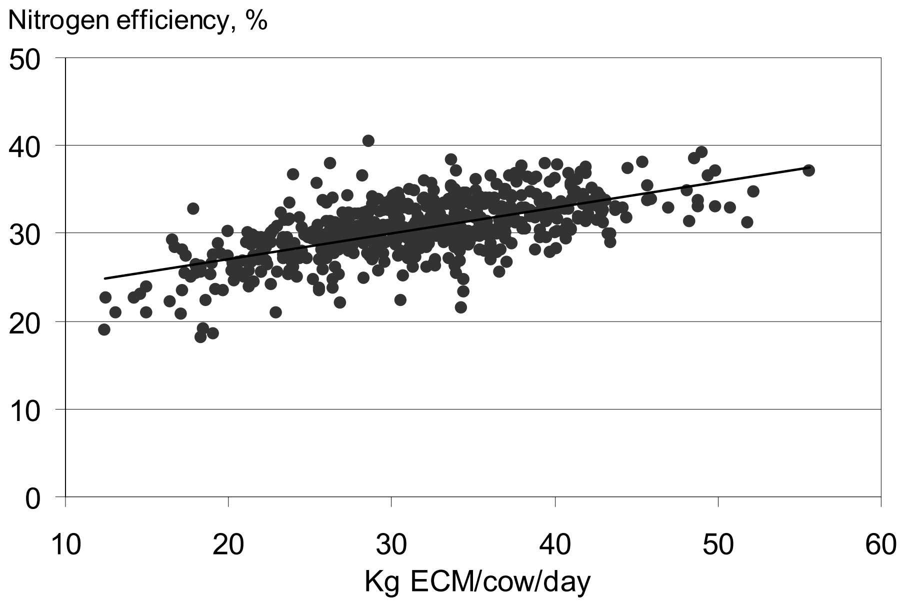

Figure 9. Relationship between amount of energy-corrected milk (ECM) and nitrogen efficiency of lactating cows before (1999-2000) and after rebuilding (2000-02) of the cowshed at Brogården ($y=0.29x + 21.2$; $R^2=0.40$; 558 observations).

Cows yielding more than 35 kg ECM/day used 32.4 – 32.8% of consumed nitrogen in feed for production of nitrogen in milk, (Figure 10.) The nitrogen efficiency for cows in mid lactation (producing 25 – 35 kg ECM/day) and late lactation cows (producing < 25 kg ECM/day) was lower, 30,2 – 30.7% and 26.5 – 28.0 respectively. In average for all lactating cows, dry cows not included, the nitrogen efficiency was 30.5 – 30.8%.

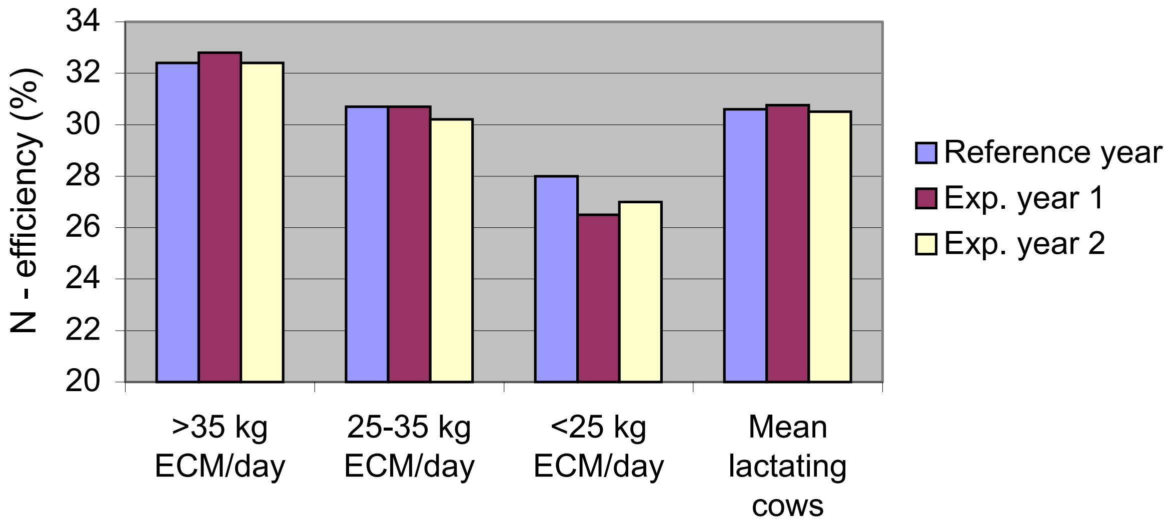

Figure 10. Nitrogen efficiency of lactating cows divided into production groups and as an average over production levels before (1999-2000) and after rebuilding (2000-01 and 2001-02) of the cowshed at Brogården

When calculating the nitrogen efficiency for all cows, i. e. full lactation and dry period, during the indoor period, the efficiency increased from 27.8% during the period before rebuilding to 29.1% and 29.8% during the first and second year following the rebuilding, respectively.

The nitrogen flow from feed to milk and manure in relation to annual milk production is illustrated in figure 11. Nitrogen efficiency improves when more of the nitrogen in feed consumed is found in the milk produced.

For a complete year (Oct.1- Sept.30), including the grazing period, nitrogen efficiency for all cows, i.e. full lactation and dry period, increased from 25.5% during the reference period to 27.5% during the two periods following the rebuilding. The lower nitrogen efficiency, when calculated on a 12 month basis, depends on the lower milk production during the grazing period than during the indoor period.

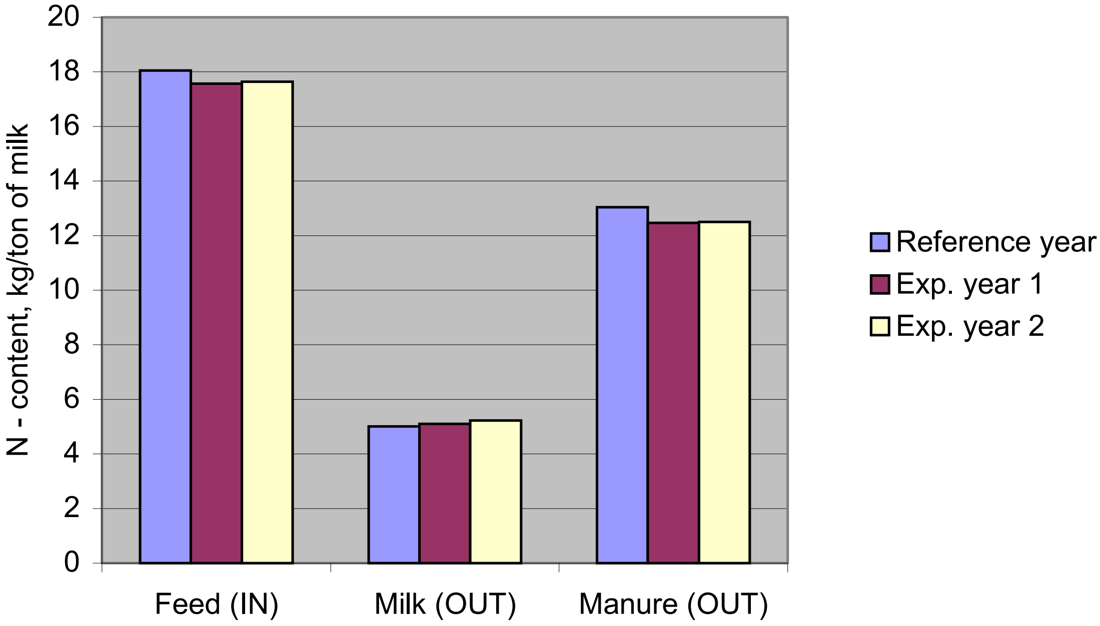

Figure 11. Nitrogen flow from feed to milk and manure in relation to 7 months production by the dairy cows, including the dry period, before (1999-2000) and after rebuilding (2000-01 and 2001-02) of the cowshed at Brogården

3.7 Animal Health Surveillance (Task 7)

Veterinary-treated diseases, claw health and cow cleanness were monitored closely.

3.7.1 Acute diseases

The prevalence of acute diseases during the summer period (May-August) and the winter period (September – April) before and after the rebuilding are shown in Table 11. During year 2000 three incidents of mastitis, all claw lesions and two other incidences occurred at an other farm, where the cows were kept during the rebuilding of the cowshed, and these incidents should be related to the situation on that farm. The cow health improved and was in general better after the rebuilding of the cowshed

Table 11. Incidences of acute diseases before and after rebuilding of the cowshed at Brogården, 1999-2000 and 2000-02, during housing (Sep.-Apr.) and grazing period (May- Aug.)

Disease	Before rebuilding		After rebuilding	
	Housing	Grazing	Housing	Grazing
Calving problem, % of calvings	3.4	0	1.4	0
Retained placenta, % of calvings	3.4	10.8	1.4	0
Milk fever, % of calvings	4.4	0	4.2	0
Ketosis, incidents/100 cow years	19.0	4.2	3.9	3.9
Teat injury incidents/100 cow years	7.4	3.7	7.7	15.1
Acute mastitis, incidents/100 cow years	68.6	34.8	30.4	3.9
Acute hoof disease, incidents/100 cow years	11.1	50.0	0	3.9
Other acute diseases, incidents/100 cow years	26.9	19.5	3.7	0

3.7.2 Hoof health

Hoof trimming of all cows was normally carried out two - three times per winter season, the first winter in Sept. –00 and in Feb. -01 and in Apr. -01 foot health status was recorded. The effect of the change in stalls and barn environment is best observed at the end of the winter season. Table 12 shows the prevalence of different lesions at the claw trimming in the springtime prior to (1999-2000) and after (2000-2002) the rebuilding of the cowshed. These records can be compared with a similar investigation carried out in west region of Sweden 1996-98 (project Kofot, Manske et al, 2002) The total prevalence of all claw injuries at each claw trimming at Brogården varied from 60-92% before to 50-72% after the rebuilding of the cowshed.

Table 12. Prevalence (percentage of cows diseased) of different claw lesions at claw trimming in the spring before and after rebuilding of the cowshed at Brogården, 2000 and 2001-02, and in the project

Claw lesion	Before rebuilding	After rebuilding
Dermatitis, %	12.3	20.5
Heel horn erosion, %[1]	29.6	6.3
Haemorrhage, %[1,2]	38.3	13.4
Sole ulcer, %	6.2	0.8
White line separation, %	16.0	5.5
Other lesions, %[3]	3.7	2.4
Any lesion, %	86.4	70.9

[1]Moderate to serious injury
[2] Bleeding in sole or white line
[3]Duble sole, warts, cracks or abnormal claw shape.

The overall claw health of the cows was fairly good before the rebuilding and improved to good or very good after the rebuilding of the barn.

3.7.3 Cleanness

The cleanness of the cows was registered once each month during the winter periods throughout the project period, always by the same person. A scoring system was applied, where the degree of dirtiness on different parts of the body was judged. Higher values indicated dirtier body part. The degree of dirtiness on different parts of the cow's body, before and after the rebuilding of the barn, is summarized in table 13. The cleanness of individual cows varied considerably. The variation between different seasons was low.

Table 13. Degree of dirtiness on different body areas before and after the rebuilding of the cowshed at Brogården, housing periods 1998-99 and 2000-01 (min-max. median values)

Body area	Before rebuilding	After rebuilding
Hind foot-hock[1]	8-9	3-4
Gaskin-thigh-rump[2]	2-3	1-2
Udder[3]	2-4	0-1

[1, 2, 3] Max scores were 12, 6 and 9 respectively

3.7.4 Herdsman's judgement

The herdsman at Brogården had been working there since 1988 and his comments to the new system were very positive: "it's like comparing day and night", "better air and not so high humidity during winter", "much more light", "cleaner stalls, cleaner cows, no grooming needed". There was never any problem to get replacement personal for holidays and weekends. Also milk farmers visiting the cowshed were very impressed by the clean cows, by the good air quality inside the barn and the high milk production.

All these judgements indicate considerable improvement in the environment for both men and animals, which is in line with the observations of the cow's health and cleanness.

3.8 Measurement of Quantity and Quality of Milk (Task 8)

The quantity of produced milk on a herd level was registered when delivered every 2 days. Analysis of protein, fat, casein, urea, somatic cell and total bacteria counts, freezing point, smell, taste and fat-index of delivered milk on a herd level basis were carried out once a week. Official milk recordings and analyses of protein, fat, urea and somatic cell counts were carried out once monthly on individual cows. Table 14 summarizes the quality of delivered milk before and after the rebuilding of the cowshed. There were only minor changes in the milk quality; the protein content increased from 3.2 to 3.3%, which gave a somewhat higher price for the milk, milk fat remained at the same level. The urea content was at a low level throughout the project period and did not decrease as expected when the low protein diet was fed.

Table 14. Quality of delivered milk from the dairy cows before (1999-2000) and after the rebuilding (2000-02) of the cowshed at Brogården.

	Before rebuilding		After rebuilding	
	Average	S. D.	Average	S. D.
Milk delivered, kg/year	324 967	7 382	368 965	5 532
Milk fat, %	4.3	0.06	4.3	0.06
Milk protein, %	3.2	0.02	3.3	0.02
Whey protein, %	0.95	0.02	0.94	0.03
Casein, %	2.24	0.04	2.35	0.07
Milk urea, mmol/l	5.1	0.33	4.7	0.38
Somatic cell counts, 1000/ml	106	17.3	109	34.7
Total bacteria, 1000/ml	10.8	1.67	9.9	0.71
Freezing point, °C	-0.532	0.0035	-0.527	0.0158
Smell-/Taste remarks	No		No	

3.9 Measurement of Ammonia in Exhaust Air (Task 9)

The measurement of ammonia in the exhaust air was carried out during the two winter periods 25/11 2000 – 4/4 2001 and 3/10 2001 – 24/4 2002.

The ammonia concentration in the exhaust air was measured with an infrared spectrophotometer. A zero gas filter containing activated charcoal was used every week to set the zero level. The measuring range was 0-50 ppm and the accuracy of the instrument was ±5% at the full scale deflection. The ventilation rate through the cowshed was continuously measured with impellers in the exhaust duct. The impellers were calibrated before and after the measuring period using a hot wire anemometer to measure the average air velocity through the cross section area of the exhaust duct. A data logger recorded the ammonia concentration and ventilation rate as well as the carbon dioxide concentration, outside and inside air temperature and air humidity. The temperature in incoming and outgoing drinking water was measured as well. During some periods the cows' consumption of water was registered by reading the water meter manually at a fixed time every day.

The ammonia release during the first period after the rebuilding of the cowshed, 2000-01 is shown in Figure 12. The rebuilding of the barn resulted in a lower emission. The total emission from the cows was reduced with about 40 %, from 24 g/cow and day to 15 g/cow and day. This was the result of low evacuation of air from the manure culvert and the urine drainage system, preventing air leakage, in combination with efficient urine separation and cooling of the manure gutters. The indoor climate improved considerably; the average ammonia concentration was lowered from 8 ppm before the re-building of the barn to 3 ppm.

Ammonia release and concentrations, ventilation rate, carbon dioxide, inside and outside temperatures and inside and outside air humidity's are presented in Table 15.

When the exhaust air passed through the biofilter, nearly all remaining ammonia in the air was absorbed, partly by the irrigation water and partly by the microbes in the filter. The air after the filter contained virtually no ammonia at all.

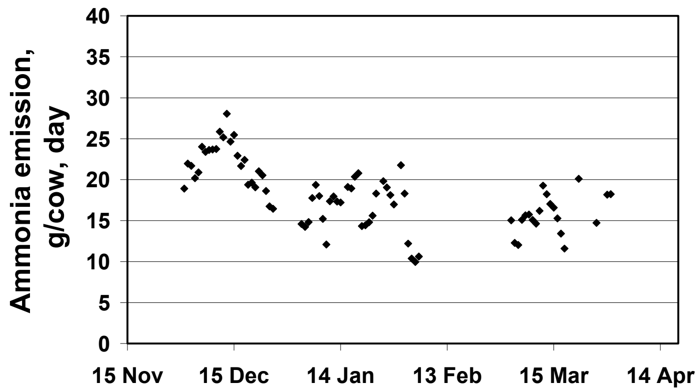

Figure 12. Release of ammonia in exhaust air before the biofilter during the first year 2000-2001 after the rebuilding.

Table 15. Results of the measurements of ammonia emission, ammonia concentration, ventilation rate, carbon dioxide concentration, inside and outside temperature, inside and outside air humidity, average of the two winter periods after rebuilding.

Parameter	Average	S. D.	Max - min
Ammonia emission g/h	29	7.1	49 – 14
Ammonia emission, g /cow and day	17	4.0	28 – 8
Ammonia concentration, ppm	3.3	0.8	5.1 – 1.1
Ventilation rate, m^3/cow and h	289	49	375 – 181
Carbon dioxide concentration, ppm	1,726	481	3,614 – 1,012
Inside air temperature, ^oC	14.7	2.3	20.5 – 9.2
Outside air temperature, ^oC	3.4	5.0	13.4 – -12.6
Inside air humidity, %	66	7.0	80 – 40
Outside air humidity, %	83	12	110 – 45

3.10 Management in Cowshed (Task 10)

A test program was followed during the winter periods following the rebuilding of the barn in order to evaluate how the different technical measures contributed to the observed changes in indoor climate and total ammonia emission. Observations were carried out with respect to the effect of ventilation rate, barn temperature, cooling of the manure gutters and exhaust air through the biofilter.

Only those measurements that had a clear impact on the barn climate and ammonia emission from the barn are described here. Other measurements such as using peat moss as bedding, less frequent manure removal and blocking the urine drainage gave no significant results and it has not been possible to explain why these actions did not have any effect on the ammonia emission. During the last winter period 2002-03 an increase of the ammonia emission was registered and this seems to be an effect of overfeeding. The feed analyses were not correct, which resulted in too much protein. Feed intake and milk production was also higher than the two previous periods, 2000-01 and 2001-02. The result and importance of correct analysed feedstuff was clearly demonstrated.

3.10.1 Ventilation rate

The release of ammonia increased with increasing ventilation rate, see Figure 13.

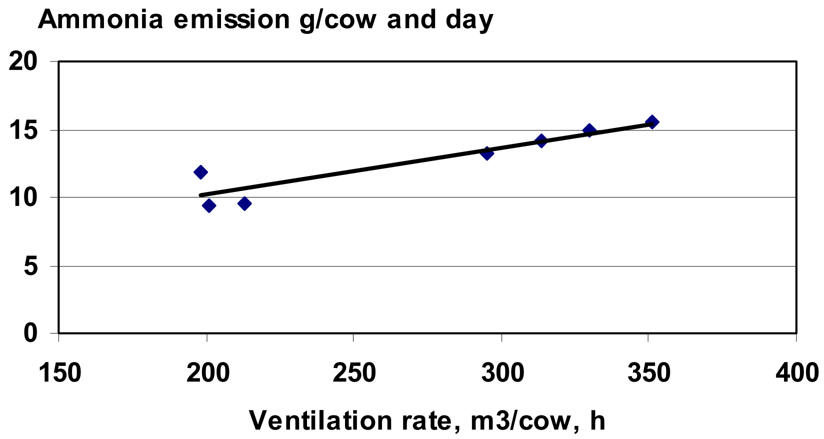

Figure 13. Relationship between ventilation rate and ammonia emission from the barn at indoor temperatures in the range of 11 to 13 °C, after rebuilding (2000-01) at Brogården (y=0.035x + 3.14; R^2=0.88; 7 records).

3.10.2 Reduced indoor temperature

The ammonia release also increased with increasing indoor air temperature inside the cowshed, see Figure 14.

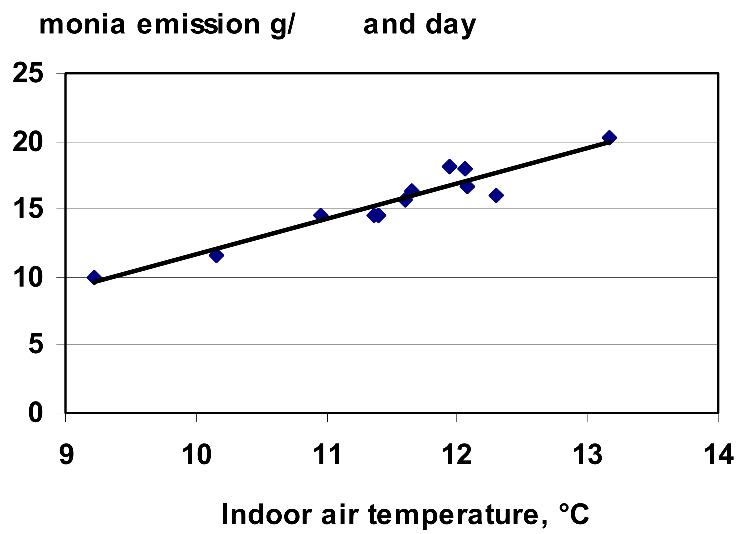

Figure 14. Relationship between indoor air temperature and ammonia emission from the barn at ventilation rates in the range of 190-230 m3/cow and h, after rebuilding (2000-02).at Brogården (y=2.60x - 14.4; R2=0.91; 12 records)

3.10.3 Cooling of gutters

The temperature of incoming drinking water raised 5–6 ºC when it passed through the plastic pipes in the bottom of the gutters, see Figure 15. The average amount of water passing through the pipes was 85 l/cow and day. The heat collected from the gutter was in the range of 1.8- 2.1 MJ/cow and day. An example of ammonia release with and without water passing through the pipes is presented in Figure 16. Cooling resulted in 20% lower release of ammonia.

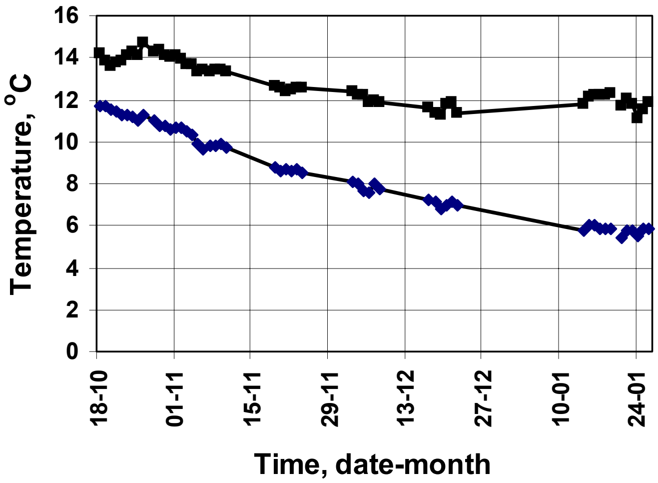

Figure 15. Water temperatures in inlets and outlets of the plastic pipes in the manure gutters.

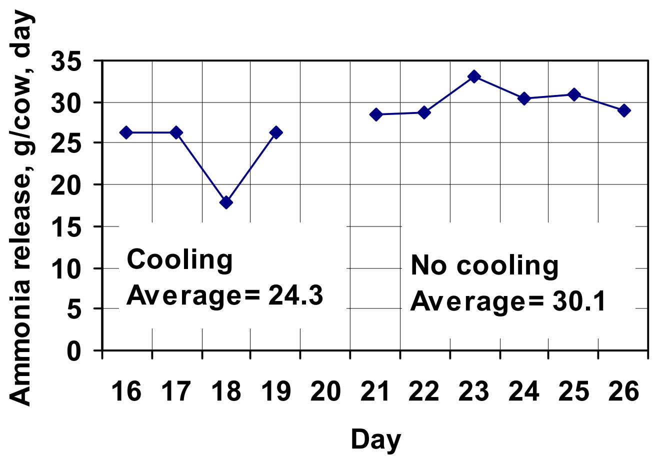

Figure 16. Ammonia release with and without water passing through the pipes in the gutters.

3.10.4 Biofilter

Only at a few occasions it was possible to detect any ammonia at all in the exhaust air from the biofilter. The highest concentration ever measured was 0.8 ppm which corresponded to a release of 4 g ammonia/cow and day.

The total ammonia losses from the barn were reduced by 83% compared with the period before rebuilding, from 24 to 4 g/cow and day, taking the full effect of the bio-filter into consideration.

3.11 Measurement of Ammonia Losses from Storage and Spreading of Manure (Task11)

After the rebuilding the urine, feaces and cleaning water was collected in a pump pit outside the barn and pumped into a storage container twice a week. The slurry store had a capacity of 1300 m^3 (diameter 22 m, depth 3.6 m) and was built in prefabricated concrete blocks. The storage was covered with a canvas roof from Netherlands, see figure 17. The roof was supported by a wooden pole in the middle and held in place by a frame fastened in the concrete blocks. The storage capacity with this system was for almost one year, in order to give better flexibility when choosing spreading time.

Figure 17. The storage container for slurry at Brogården, with a canvas roof.

During the period from January 2001 to February 2002 ammonia evaporation from the new covered storage was monitored using the micrometeorological method with passive flux samplers. The sampling was repeated 6-8 times during the year and the total ammonia emission could be calculated, see figure 18. The ammonia lost during the storage period was calculated to be 0.2 kg NH_3-N/cow and year, corresponding to less than 1% evaporation.

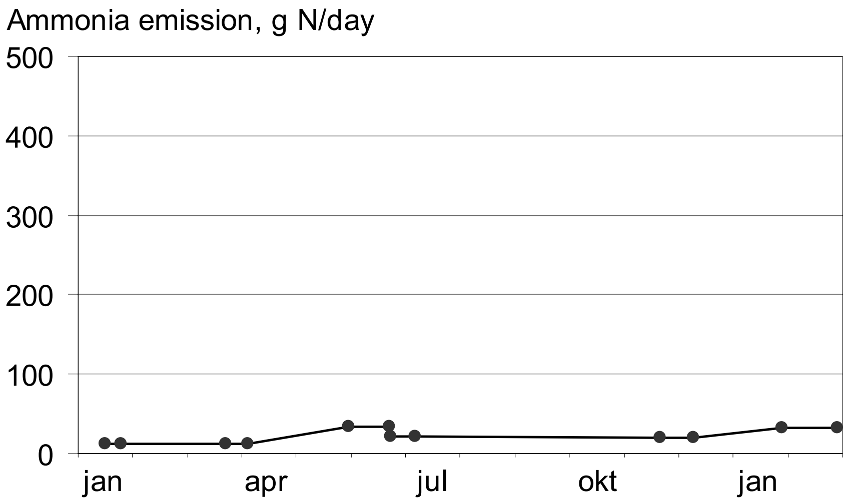

Figure 18. Ammonia emission during storage of slurry after rebuilding (January 2001 to February 2002; 6 measuring periods) of the barn at Brogården,

The ammonia losses during the storage period was reduced wit 95%, compared with the period before rebuilding of the cowshed at Brogården.

The content of minerals and pH value of the stored slurry are summarised in table 16. Samples were taken in connection with spreading. The content of nitrogen, phosphorus and potassium were comparable with other slurry from cows according to investigations carried out by JTI. The dry matter content in the slurry from Nov 2001 seems low and might be a result from the summer feeding, when cows were grazing.

Table 16. Analyses of slurry from the storage container, before spreading losses, after rebuilding of the cowshed at Brogården.

	May 2001	Nov 2001	May 2002
Dry matter content, %	6.7	5.0	8.0
Total-N, kg/ton	3.2	2.8	2.9
Ammonium-N, kg/ton	1.4	1.5	1.6
Phosphorus , kg/ton	0.6	0.6	0.6
Potassium, kg/ton	2.5	2.8	3.0
pH	7.3	6.9	6.9

3.11.1 Spreading of manure

All slurry could be spread with one spreader using best technique for reducing ammonia emission. Both band spreading and shallow injection, was used in the first season after rebuilding of the barn. Basically the slurry from a cow farm should be spread on grassland, but due to the risk for contamination of the grass and so risk for bad quality of forage this strategy was not implemented.

Figure 19. Band spreading of slurry in growing crops (spreading in the spring)

In order to test different techniques the main amount of slurry, 60%, was spread in growing wheat in the spring time with a spreader equipped with a 12 m ramp having trailed hoses, band spreading, see figure 19. The remaining 40% was injected on grassland in the autumn, see figure 20.

Figure 20. Shallow injection of slurry on ley (spreading in autumn)

The ammonia emission was measured during and after spreading and a total of three measurements were recorded. The result from these spreading occasions are summarised in table 17.

Table 17. Summary of results from spreading of slurry after the rebuilding.

	Band spreading May 2001	Shallow injection Nov. 2001	Band spreading May 2002
Crop	Growing wheat	Ley	Growing wheat
Slurry application, ton/ha	38	27	36
Total N application, kg N/ha	122	76	-
Ammonium application, kg NH_4-N/ha	53	41	59
Ammonia losses,			
kg NH_3-N/ha	9	2.5	8
% of total N applied	7	3	-
% of ammonium-N applied	16	6	13

The ammonia losses during spreading were 13 – 16% with band spreading and 6% with shallow injection.

The new spreading strategy with slurry reduced the ammonia losses with 40%, calculated on farm level.

4 NITROGEN FLOW ON FARM LEVEL

4.1 Housing

The ammonia released inside the cowshed decreased from 7.2 before to 5.0 kg NH_3-N/cow and year after the rebuilding. It was very difficult to isolate the effect of different technical solutions or management routines. The only thing that had a clear effect on the ammonia release was cooling of the manure gutters with incoming drinking water. The bio-filter was very efficient and when the effect of this is taken into account the ammonia released from the cowshed was only 1 kg NH_3-N/cow and year.

4.2 Feeding

The changes in the feed ration increased the nitrogen efficiency from 25 to 27%, calculated on full lactation. The new feeding strategy increased both feed intake and milk production and with the improved efficiency the nitrogen in manure and urine decreased from 76 to 73 kg N/cow and period, 1 Oct. – 30 Apr., not including grazing and manure on fields during summer. Milk production increased during the project period from 30.6, during the winter period before rebuilding, to 33.0 kg ECM/cow and day during the winter period 2001-02. The feed consumption increased at the same time from 18.5 to 20.4 kg DM/cow/day. How much of the change of nitrogen from the cows influenced the ammonia level inside the barn was not possible to measure.

4.3 Manure handling

The change to a slurry system with a covered store in the ground reduced the storage losses from 4.1 to 0.2 kg NH_3-N/cow and year.

The slurry system with higher storage capacity also meant that a new spreading strategy could be implemented. The main part of the slurry was applied with band spreading in growing crops in the springtime and a minor part was injected in grassland during autumn. In this way the ammonia losses could be reduced from 10.4 to 6.1 kg NH_3-N/cow and year.

4.4 Total emission

All detailed measurement in the barn was carried out during the winter periods, so the losses below are calculated for 7-months periods. In total the ammonia losses from Brogården decreased from 524 kg NH_3-N/ 7 months the year before rebuilding the cowshed (1999-2000) to 153 NH_3-N/ 7 months after the rebuilding, when the effect of the biofilter is included. See figure 21.

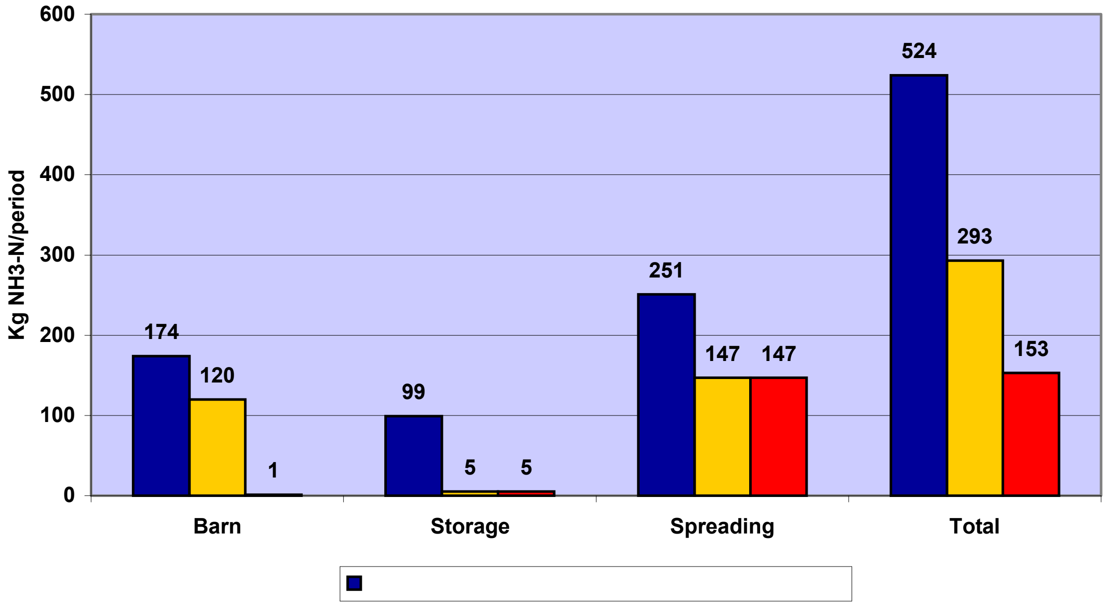

Figure 21. Nitrogen losses during the winter periods before and after the rebuilding of the cowshed at Brogården

4.5 Mineral balance

A mineral balance describes the flow of different minerals within a limited region or area. e.g a farm. The result shows if there is surplus or deficit of minerals and how well these minerals are used on the farm. All products brought into the farm are put in relation to all minerals brought out from the farm. Normally this calculation is made for the three main minerals; nitrogen (N), phosphorus (P), and potashes (K). One method often used is the Farm-Gate method taking into account all minerals into the farm and all minerals out from the farm. Minerals circulating on the farm, such as feed and manure are not included in the calculation. See figure 22. As this project was focused on nitrogen balance only this mineral is shown.

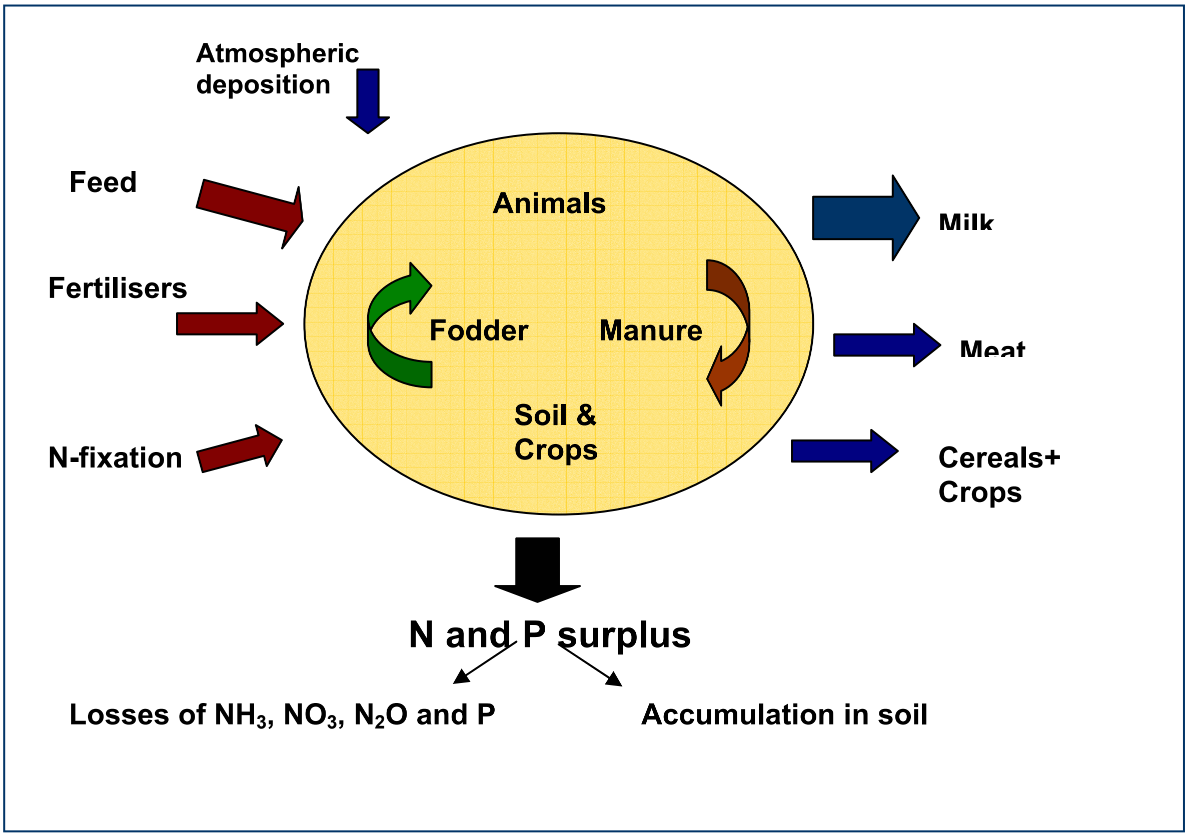

Figure22. Schematic picture of the mineral flow on farm level according to the Farm-Gate method.

In Table 18 the amount of nitrogen fixation by clover was assumed to be the same before and after the rebuilding and the amount of roughage from the farm is not included.

Table 18. Nitrogen flow at Brogården acc. to the Farm-gate method before and after the rebuilding of the cowshed.

		kg N Before 1999-2000	After ave. 2000-02	Difference Before- After
Nitrogen IN				
Barn	Purchased feed cows	3,670	3,877	207
	Feed youngstock	76	69	-8
	Litter	26	0	-26
	Total	3,772	3,946	
Crops	Mineral fertiliser	13,242	9,737	-3,505
	Seed	193	188	-6
	Fixation by clover	1500	1,500	0
	Atmospheric deposition	435	435	0
	Total	15,370	11,860	
Total in		**19,142**	**15,805**	**-3,337**
Nitrogen OUT				
Barn	Milk	1,636	1,919	283
	Animal	275	275	0
	Total	1,911	2,194	
Crops	Grains	6,482	6,015	-467
	Straw	735	596	-139
	Total	7,217	6,611	
Total out		**9,128**	**8,805**	**-323**
Surplus	**Total on farm**	**10,014**	**7,000**	**-3,014**
(in-out)	**kg/ha (94.6 ha)**	**106**	**74**	**-32**
Output as % of input		**48**	**56**	

The big difference in nitrogen in is the purchase of mineral fertiliser. In average there were 3,500 kg less fertiliser bought in during the two years after the rebuilding. There are several reasons for this change:

- The balance between autumn sawn and spring sown cereals. During the year before the rebuilding there was about 17 ha more autumn planted wheat than spring planted cereals. Generally autumn planted wheat gets more nitrogen fertiliser, (about 60kg) than spring planted cereals.
- The overall application of nitrogen (including plant available ammonia in slurry) was reduced, for autumn planted wheat with about 30 kg N/ha and for spring planted cereals with about 25 kg N/ha.
- With the changes in manure handling system more nitrogen in the slurry could be kept and be used by the plants. About 700 kg N less mineral fertiliser was purchased due to this on Brogården.

Figure 23 shows the nitrogen flow at Brogården during the year before, 1999, and an average of the two years, 2000 and 2001, after the rebuilding of the cowshed.

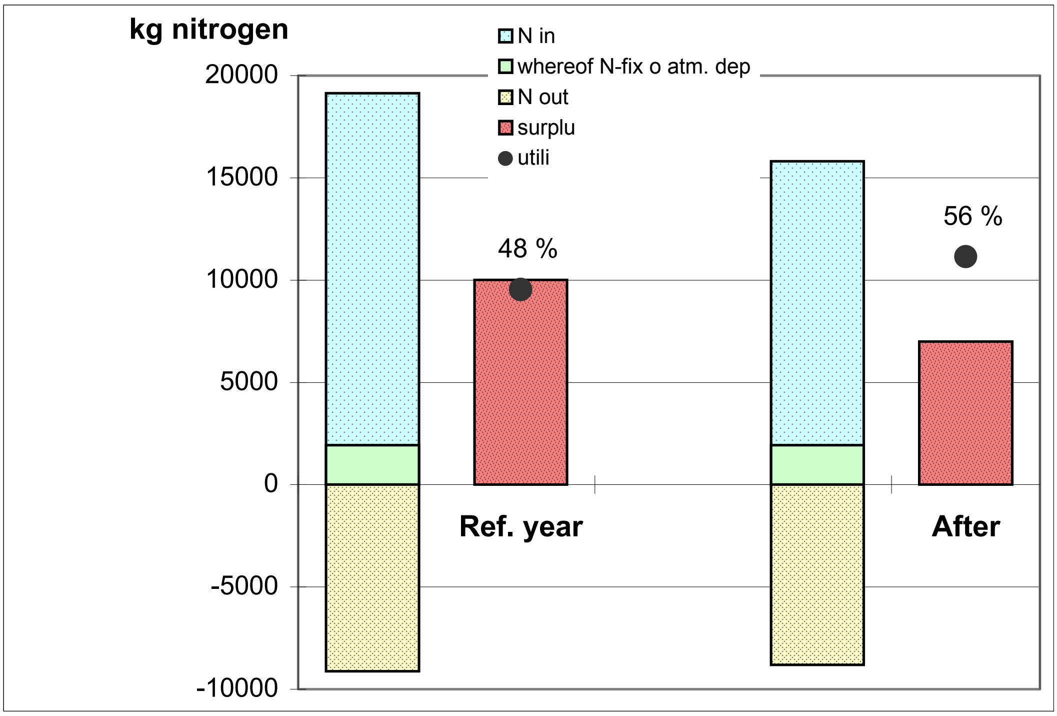

Figure 23. Nitrogen balance before and after the rebuilding of the cowshed at Brogården

5 ECONOMY

In this economic analyse of the results from the project four different sectors have been studied: (1) adjustments of the protein level in the feed ratio, (2) to use best suitable technique for stalling, ventilation, manure handling, and management inside the cowshed, (3) to change to liquid manure handling with storage in a covered container and (4) use best known technique for spreading of slurry. Analyse of the feed rations has been done for 7-moths periods, the winter before the rebuilding and the three winter periods after the rebuilding.

5.1 Feeding

Table 19 summarises some key figures for the four periods studied. The milk price has been calculated using Arla Foods pricing system. The fat and protein contents have been considered, as well as seasonal variations and final payments. The cost for roughage has been calculated, using the content of energy and protein as a base. Purchased concentrate have a value based on actual purchase price. The price for a feed stuff used has been calculated as the average value over the four years, in order to avoid seasonal effects. The feed costs only included costs for consumed feed, waste feed is not included.

Table 19. Produced/delivered amounts of milk, fat-and protein content, milk revenue, feed cost and nitrogen per 7-mo period, before and after rebuilding the cowshed.

	Before, 99-00	After, 00-01	After, 01-02
Produced milk, kg /lact. cow and day	30.1	31.1	31.9
Delivered milk, kg /lact. cow and day	30.8	29.3	32.8
Delivered fat, kg/cow and day	25.6	25.0	25.6
Fat, %	4.34	4.27	4.34
Protein, %	3.33	3.25	3.33
Milk revenue, SEK/ kg milk	2.98	2.94	2.98
Feed cost, SEK/ kg milk	0.95	1.01	0.96
Milk – Feed SEK/kg milk	2.03	1.93	2.03
Feed, kg DM/kg milk	0.62	0.69	0.67
N-efficiency. %	27.4	29.1	29.8

From an economic point of view it is more interesting to analyse the production in terms of delivered milk. The two first lines are showing the production, calculated on lactating cows, the remaining lines are calculated on average cows, including the dry period.

The production, fat-and protein contents and the revenue for milk must be considered as fairly high at Brogården, compared with other farms in the region. The feed costs, calculated per kg/milk delivered, are fairly low, compared with similar farms in the region. The real feed costs have been somewhat higher as some silage and hay had to be discarded due to bad quality caused by bad wheather.

During the first winter months, Oct.-00 – May-01, after the rebuilding the milk production decreased, but increased again during the remaining months of the control year. This is most likely caused by the changed condition at the second farm, where the cows spent the summer 2000, when the cowshed was rebuilt. With lower production and more feed consumed the feed costs increased during the winter period 00-01. During this period the milk revenues also decreased due to lower content of protein and fat. All together this gave a lower milk net income the first winter period after the rebuilding.

For the average cow the milk net income (revenue less feed costs) increased the following two periods.

Despite higher feed consumption the N-efficiency was improved. Good management routines and frequent controls had positive effects, on milk production, milk price and on N-efficiency.

5.2 Investments in building and equipment

There are several ways to describe the effect of an investment and its economic impact on N-losses. One way is to put the cost for an investment in relation to its potential for ammonia reduction in SEK/kg N. This figure indicates which price a kg N should have in order to make the investment interesting. A second alternative to show the economic benefit with an investment is to calculate the value of reduced ammonia losses, where the value of nitrogen is put to 8 SEK/kg.

The capital costs for the investments, see table 20, have been calculated as fixed annual investments. The interest has been assumed to be 6 %, the economic lifetime between 5 and 30 years, depending of type of investment, and the rest value thereafter is set to zero. The bio-filter also had a yearly maintenance cost.

Table 20. Capital cost for reduction of ammonia losses from the barn, from storage and at spreading manure at Brogården.

	Cowshed, total	Bio filter	Cooling	Manure handling	Manure spreading
Less N-losses, kg N/cow and year	6.2	4.0	1.4	3.9	4.3
Value of less N-losses, SEK/year	2,083	1,333	470	1,307	1,446
Investment SEK	1,230,660	280,770	64,770	1,145,930	0
Capital cost/increased spreading cost	170.19	33.50	6.67	125.50	0
Cost for less N-losses, SEK/kg N	654	229	110	768	1

The costs related to the cows stands and improved environment inside the cowshed were SEK 1,230,660. The rebuilding costs related to feeding were 363,000. Further to these costs there were costs for general improvement of the cowshed, not direct related to the project.

The effect of cooling of the manure gutters and the bio filter were clear and could be calculated. The bio filter had a yearly maintenance cost of about SEK 4,700. Despite the very good effect of the bio-filter, the economic effect of cooling is bigger when related to the cost for reduction of ammonia losses; 229 SEK/kg N saved for the bio-filter and 110 SEK/kg N saved for cooling.

The positive effect of cooling the manure gutters on ammonia losses also increased the temperature of the cow's drinking water. The water temperature rose with about 5-6 °C and from other studies it is known that this has a positive effect on the milk production. This effect could however not be isolated on Brogården. The good environment inside the cowshed was also appreciated by the herdsman and relief personnel working there. The warmer drinking water and the good working conditions might have had positive effect on the economy in milk production, but this is very difficult to measure.

The new slurry system reduced the ammonia losses by 3.9 kg N/cow and year. The value of this nitrogen was 1,307 SEK/year. The investment for the slurry system, including pump pit, slurry pump, pipelines, storage and roof was SEK 1.146,000. Out of this 220,000 was related to the roof. The capital costs for these investments are SEK 125,506 and 29,891 respectively. The cost for the new slurry system was calculated to 768 SEK/kg N saved.

By using best available spreading technique for slurry the losses could be reduced by 4.3 kg N/cow and year. The value of this nitrogen was 1,446 SEK. All manure spreading at Brogården was done by contractors with a fixed rate, either per hour or per cubic meter. When comparing the bills for solid manure and urine spreading before the rebuilding with slurry spreading, after the rebuilding there is only a minor difference, some hundred SEK, so the costs for the both spreading system can be regarded as same. Spreading cost per cubic meter for slurry and urine, spread with band spreader, was SEK 16, for solid manure SEK 43 and for slurry injection SEK 25.

The rebuilding of the cowshed at Brogården was by many regarded as rather expensive and an "average" farmer could not afford these investment. There are several reasons for the relatively high cost at Brogården:

- The Life Ammonia project was a demonstration project and new techniques was to be shown and tested.
- Brogården was a state owned farm and any reconstruction is subject to a number of rules and regulation, inspection during and after the construction period, documentation etc. The rebuilding was implemented during a short period of time and no work was carried out by the farm employees. An "average" farmer would probably do as much work as possible himself during a longer period.
- Rebuilding of an old building can be more expansive than building new. Some of the installations, e.g. plastic pipes in the concrete when making a new manure channel is marginal cost. Rubber slats can improve the cow health, cleanness and improve the milk quality.

The improved spreading technique was the measurement that was most cost efficient at Brogården; hardly no additional cost and reduced ammonia losses. This however requires that the whole handling system before is built for slurry.

6 DISSEMINATION

Table 21 shows the revised dissemination plan. The originally planned seminars for farmers and farm advisers were to a large extent replaced by more comprehensive information via the Internet. We also reached a number of advisers at the conferences in Alnarp, Kalmar and Skara. In general the project management felt that information about the project and the results from the different trials reached the target groups; milk producers, advisers, the Swedish Board of Agriculture, students and researchers with the agriculture sector. A close co-operation with "Greppa Näringen" was another channel for distributing information. Some channels, originally mentioned in the Inception Report, Carrefour and the Feed Industry, have not shown any further interest of co-operation.

Table 21. Revised Dissemination Plan.

Activity		**-99**	**2000**				**2001**				**2002**				**2003**			
		Q4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
Internet home page	Planned																	
	Realized																	
Printed leaflet	Planned				x													
	Realized				x													
Flexible screen display	Planned																	
	Realized																	
Report from analyse of present situation	Planned			x														
	Realized			x														
Report from reference measurements	Planned					x												
	Realized						x											
Printed pamphlet	Planned							x										
	Realized													(x)				
Presentation at international conference	Planned								x								x	
	Realized														x	x		
Presentation at Swedish conference	Planned (no)																	
	Realized				x										x	x	x	
Articles in agricultural journals	Planned			x		x		x			x			x			x	
	Realized					x			xx			x			x	x	x	
Printed advice to milk producers	Planned																x	
	Realized																x	
Study visits to project site	Planned			x		x		x				x				x		
	Realized					x	x	x	x	x	x	x	x	x	x			
Reports to the Commission Progress Reports	Planned			x		x				x		x		x				
	Realized																	
Inception, Interim and Final Reports	Planned	x								x								x
	Realized	x						x										x

Following a plan worked out in March, 2000 and a co-ordination meeting in May, 2000 the work with an Internet home page started in June, 2000. An IT-consultant was engaged and the domain www.ammoniak.nu was established. The site was made public on Oct. 3. 2000. The home page served as a channel for both internal (restricted access) and external project information and services, such as minutes from project meetings, basic facts about the ammonia problem, reports from Task 1 (Reference Measurements), Task 2 (Analysis of present situation), up-to-date information about progress in project activities, practical hints for producers and advisers, etc.

Information on the home page has to some extent replaced the originally planned printed information. The website worked very well and it was used by many as a source of information about ammonia emission and its influence on the environment. The first weekly statistics indicated some 100 – 400 accesses per day. From March 2002 a more detailed statistic over monthly visits on the website, See Figure 24.

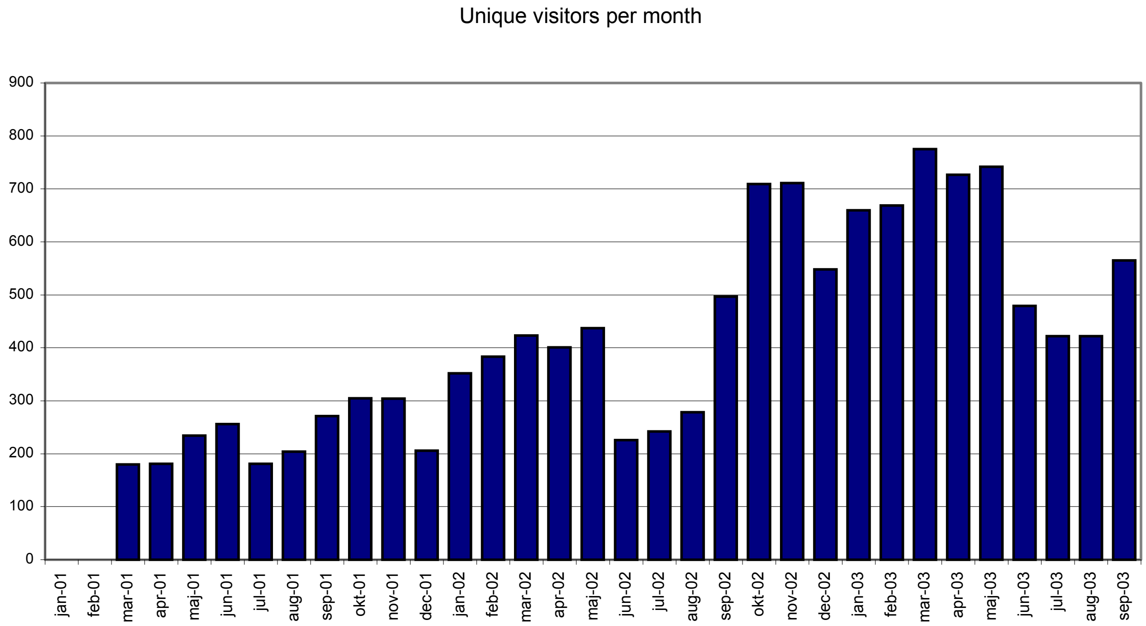

Figure 24. Unique visitors to the Internet website.

A pamphlet and a flexible exhibition screen presenting the project were prepared. These were used for the first time at a national agriculture conference at SLU in Uppsala Nov. 6-7, 2000. The inauguration of the rebuilt cow barn on Dec. 6, 2000 was covered by local and national agricultural press.

The cowshed at Brogården has been visited by a number of groups and organisations, e.g. agricultural schools, local groups of the Farmers Union, cow breeding organisations and different groups of farmer. The total numbers of visitors was around 1 600. Members of the project organisation were also invited as teachers at some "Farmers meetings", arranged by private advisers (e.g. Hallands Husdjur) and government advisers (Länsstyrelsen), especially as further education within the program REKO in Västra Götaland, Jönköping and Gotland. At two occasions, 25/9 2202 and 30/7 2003 the project Manager presented the project at conferences arranged by Jordbruksverket (The Swedish Board of Agriculture) for their advisers.

The project was presented at a number of national and international conferences and exhibition.

National conferences in Sweden

The Royal Academy of Forest and Agriculture: 22/10 2001, "Less ammonia losses in feed production, feed conversion and in manure handling". Project presentation by J-O Sannö.

Alnarps mjölkdag, 6/2 2003, arranged by JBT at SLU campus Alnarp covering actual research in milk production system, intended for farm advisers, farm building designers and students. Project presentation by J-O Sannö, "Milk production with minimum effect on the environment – experience from the Life-Ammonia project at Brogården, Skara. About 170 participants.

Djurhälso&Utfodringskonferens in Kalmar 19-21/8 2003. Animal Health & Feeding conference arranged by the Swedish Dairy Association for their advisers and veterinarians. The results from the project were presented:

- Overall objectives and results by J-O Sannö, HMH, SLU
- Animal health observation by J. Hultgren, HMH, SLU
- Feeding trials by E. Nadeau, JVSK, SLU

Smedjeveckan, Skara 24/9 2003. Within the frame of annual seminars held at the SLU campus in Skara the results from the project were presented by the project partners. The seminar were intended for farmers, student and advisers:

- Overall presentation and summary of results by J-O Sannö, HMH, SLU
- Animal health observation by J. Hultgren, HMH, SLU
- Feeding trials by E. Nadeau, JVSK, SLU
- Manure storage and spreading by S. Karlsson, JTI
- Mineral balance on farm level by C. Cederberg, Svensk Mjölk/Arla Foods
- Economical aspects by J-O Sannö

International Conferences

The project and tests carried out were presented at international conferences, in Denmark, Italy and Norway:

CIGR/NJF conference, 1-4/6 2003 in Horsens, Denmark, ”Gaseous and Odour from Animal Production Facilities”

1. J-O Sannö. et al. **Reduction of ammonia emission in milk production – a practical study.**
2. G. Gustafsson. et al. **Techniques to reduce the ammonia release from a cowshed with tied dairy cattle.**

Annual Meeting of the European Association for Animal Production, Rom, 31/8– 3/9 2003
Full paper and presentation by G. Gustafsson. et. al. **Techniques to reduce the ammonia release from a cowshed with tied dairy cattle.**
and a poster presented by E. Nadeau. et al. **Improved nitrogen utilisation by dairy cows fed low crude-protein diets containing grass/clover silage and hay as only forages.**

The Skjervold Symposium “Early harvested forage in milk and meat production”. Nannestad, Norge, 23-24 Oct 2003. a poster presentation by E. Nadeau, et al. **Dry-matter intake, performance and nitrogen efficiency by dairy cows fed low crude-protein diets.**

Exhibitions

The flexible screen was used at several exhibitions and conferences. During the project period the screen was updated twice, in order to present actual results from the tests carried out. Normally the screen was shown in the visitors room in the cowshed at Brogården and then used at exhibition stands occasionally.

- Agricultural conference at SLU campus Ultuna 6-7/11 2000, for researchers and students
- Agricultural conference at SLU campus Ultuna 19-20/11 2002, for researchers and students
- MILA agriculture exhibition in Malmö 5-8/2 2003. (10 000 visitors)
- ELMIA agriculture exhibition in Jönköping 22-25/10 2003. (25 000 visitors)

6.1.1.1 Leaflets, brochures and publication

A leaflet presenting the project was produced in the autumn of 2000 and printed in Swedish and English. This leaflet was updated and reprinted in Nov 2001. This leaflet was handed out to all visitors at Brogården, on conferences and exhibitions.

A compendium with the facts and figures from the reference year and the first year after the rebuilding was prepared in autumn of 2002 and based on this a special report in the SLU publication series "Fakta Lantbruk" (Facts Agriculture) was published in Nov. 2002 and was distributed on the Agricultural conference in Uppsala. Arla Food distributed this leaflet to all their members, about 7 500 milk producers. This publication replaced the originally planned pamphlet, see Appendix E.

During the project period a number of articles were written about the project, both in agricultural magazines and in local press. In the beginning these articles were focused on the new project for the research farm Brogården and the objectives of the project. Later the agricultural magazines reported about the results from the trials and observations. Some local papers also reported about the overall findings and results. Copies of these articles are enclosed in Appendix I.

There were also two radio interviews with the Project Manager, one for the Swedish Radio News, Ekot "Big environmental problem in agriculture can be solved", and one for the local radio station in connection to the seminars during Smedjeveckan.

Further to this the sub-contractors/partners reported in their own magazines about the project. The Project Manager also wrote an article for DeLaval, published on the special website, www.milkproduction.com, 28/4 2003.

Based on the general background information and results from the tests and observations a brochure "Prakiska råd från projektet Life Ammoniak" (Practical advises from the project Life Ammonia) was printed and distributed in September 2003 to almost 18,000 milk producers, advisers and other readers of the magazine "Husdjur", a special magazine for milk production. The brochure had 10 pages and contained 8 different advices for reducing the ammonia emission within the field of feeding, barn design, manure handling and manure spreading:

- Reduce the crude protein concentration of the feed ration.
- Analyse your feed.
- Avoid high temperature in the cowshed and in the manure.
- Reduce the dirty areas in the building.
- Build manure storage with enough capacity.
- Cover the manure store.
- Choose the right spreading time.
- Choose the right spreading technique.

All results from the different trial and measurements were put together in one publication, produced at the Department of Animal Environment and Health, SLU, Skara. Authors were the chairmen/women in the different work groups and the Project Manager. See Appendix H.

6.1.1.2 Other publications

Based on the data collected during the project period two scientific articles are under production, one concerning indoor climate in the barn by the Department of Agricultural Biosystems and Technology, Alnarp (JBT), and one covering the feeding trials by the Department of Agricultural Research Skara, Skara (JVSK). These will be published in E-Journal of CIGR and in Animal Science, respectively, in the beginning of 2004.

7 EVALUATION, CONCLUSION AND ENVIRONMENTAL BENEFITS

The Life Ammonia project at the research farm Brogården at SLU in Skara demonstrated the possibilities to reduce ammonia emission from a typical Swedish milk producing farm. The reduction of ammonia losses was achieved by (1) improving the nitrogen efficiency in milk production, (2) creating indoor climate and conditions that reduced ammonia release, (3) catching the ammonia in the outgoing air from the barn in a bio filter, (4) storing the slurry in a covered container and (5) using best available technique for spreading manure. In all the ammonia emission from the farm was reduced by 70%, when the effect of the bio filter is included. If the bio filter is not included the reduction was 40%. The ammonia losses per ton milk delivered was reduced from 2.3 to 0.7 kg, including the bio filter.

The following conclusions can be made from the project:

- A nitrogen efficiency close to 31% is realistic for traditional Swedish dairy farms, using grass silage and concentrate, preferably with some dried sugar beet pulp (Betfor) added.
- The protein concentration 160-170 g/ kg DM is realistic for cows in early lactation. This concentration has the potential to increase the milk production and at the same time reduce the losses of ammonia from the manure. The better the management and follow up of production is the lower the protein content can be.
- Increased individual milk yield improves the nitrogen efficiency.
- Slurry handling system gives several possibilities to reduce the ammonia emission during storage and spreading of the manure.
- When building a new shed or making an extension of an existing building is it important to plan for a slurry storage, big enough to allow for spreading during good conditions.
- A cover on the slurry or urine storage minimise the ammonia losses but, to a relatively high cost. There are other alternatives that are less expensive, but these might require more attention and maintenance.
- Band spreading and shallow injection are spreading techniques that can be used in different crops and, normally, keeps ammonia losses at a low level. At the same time the smell from spreading is minimised. Slurry spread with better control of the application rate also results in less contamination of the plant.
- The changes that were implemented at Brogården improved the nitrogen balance on the farm. The nitrogen in the slurry was better utilised and less mineral fertiliser was needed.

The plant production on Brogården was relatively extensive in relation to the milk production. This means that changes in milk production can be shadowed by small changes in the crop production. This can be demonstrated by the balance autumn planted/spring planted crops. The different needs for nitrogen when this balance was changed was much higher than the amount of nitrogen in purchased concentrate for the cows.

The project has demonstrated a number of techniques to reduce the ammonia losses from a farm, but this must be put in a wider perspective. The farmer is not paid any extra for the milk produced on a farm with low ammonia emission than on a farm with high emission. The small profit, if any, from a milk producing farm can not cover all the investments made in this project, but this is a matter of political decisions taking other aspects into consideration, such as, low consumer price for milk and meat, open landscape for all, employment in the agriculture sector. etc.

Within the frame of the Swedish government's goal to reach the targets set in the 15 "Swedish Environmental Quality Objectives" regional and local programs for reduction of ammonia losses have been worked out. Almost 4, 000 farmers have joined the advisory service Greppa Näringen, and stricter rules for storage and spreading of manure will be enforced. The project Life Ammonia certainly contributed to focus on one of the environmental problems and to demonstrate on the possibilities to achieve improvements.

7.1 The project process, output and environmental benefits

The project process worked well, the different working groups carried out their work as planned and the different tasks were implemented, basically, within budget and in time. The major modification was early in the project when the partners, of practical reason, became sub-contractors. The internal staff policy at SLU delayed the employment of a full time Project Manager, which meant that a provisional Project Manager had to take responsibility for the project beside his ordinary job. The project would of course have benefited of a full time Project Manager from the start in Oct. 1999.

The project organisation was clear, Se figure 1, and a contract between the beneficiary and the sub-contractors set the guidelines and limits for the project work. The Project Manager was assigned to the Management Group and acted as secretary at the Groups meetings.

The Project Manager, together with the administration at HMH, worked out an accounting plan that was used on top of the accounting system within SLU. The total budget was split up into a 3-months budget, which was used for follow every 3 months. This system worked very well and has later been used for other projects within the department.

The sub-contractors contributed with their special know-how to a wide intellectual base for the implementation of the project. The only disappointment was that IVL Swedish Environment Research Institute Ltd had to withdraw from the project due to insufficient funding. Their role was taken over by JBT and the planned measurements were carried out as a complement to the continuous data logging in the cowshed. The combination of sub-contractors from the University, farmers' co-operatives, institutes and private sector was of course a risk, but everybody had strong connections to the milk sector in Sweden and were devoted to find the best solution for the project. The network these partners represented was also used for transfer of information, such as conferences, exhibitions and distribution of brochures.

The reproduction potential of the techniques and methods used is high for this type of housing system. Still almost 75% of all cows in Sweden are kept in stanchion barns and many of these are extending their cowsheds with 20-40 cow places, and the techniques for stalling, manure handling, feeding, ventilation could be used in these cowsheds. Other basic findings in the project, especially the importance of low surface temperature in channels for manure and urine separation can be used for loose housing system. There are new manure scraper systems on the market having urine separation and scraper blades with rubber. The effect of decreasing the protein in the feed ration is obvious and can be implemented by any farmer. Handling and spreading of slurry in the best way reduce the cost for mineral fertiliser. A slurry system also provide other advantages than low ammonia evaporation, such as easier handling, better distribution of manure and less labour cost.

The cost/benefit analyses indicate that some of the techniques used are not feasible for "average" farmers. The bio-filter proved to be very efficient but would be very difficult to build in a new loose housing system with s.c. natural ventilation without fans. The manure legislation already state that manure stores should be covered and urine stores in south Sweden must have a tight roof, whereas a floating layer of straw is accepted for slurry. The roof used at Brogården reduced the ammonia losses with about 95%, compared with the old system. The losses were less than 0.5%. The cost for each kg N saved (in total 4 kg/cow and year) was about SEK 180 compared to SEK 8 when purchased as mineral fertiliser.

The basic results achieved in the project would by very useful in other, less developed countries around the Baltic sea. The major issue would be an efficient use of the manure produced, to make sure that it is used in the plant production, in such a way that ammonia emission is minimised. The farmer might need subsidies to build proper storages and purchase efficient spreaders. An advisory service would help the farmers to feed the cows in the correct way, which most likely would increase the milk production (higher profit) without increasing ammonia from the production.

7.1.1 Comparing the project objectives

The original objectives in table 2 can not easily be compared with the actual outcome, see table 22.

Table 22. Nitrogen flow during he winter period before (Okt-99 –Apr-00). and the average of the two winter periods (Okt-00 – Apr01 and Oct-01 – Apr-02) after the rebuilding of the cowshed at Brogården.

	Actual results	
Winter periods **October - April**	**Before rebuilding** **Kg N/cow**	**After rebuilding** **Kg N/cow**
Total in feed	**105.7**	**100,2**
In products	-29.4 (28% of N in feed)	-29.5 (30% of N in feed)
Total from cow	**76.3**	**70.7**
Difference between calculated and measured in manure	-16	+0.4
Lost to air in cowshed	-4.2 (6%)	-2,9 (4%)
Total to storage (measured)	**56.4**	**68.2**
-in faeces	42.0	
-in urine	14.4	
Lost at storage	-1.5	-0.1
-from faeces	-1.1	
-from urine	-0.4	
Total to spreading	**54.9**	**68.1**
Lost at spreading	-6.1	-3.7
-from faeces	-3.3	
-from urine	-2.8	
Total left to crops (of **total** N from cow)	**48.8** (64%)	**64.4** (91%)

The summer periods are not included as no measurements were carried out on grass consumption or on ammonia losses at pasture. There is a rather big difference, 16 kg, in calculated amount of N in manure and actually measured during the period before rebuilding, but hardly no differences during the two periods after the rebuilding. Obviously it is much easier to measure and to analyse slurry in a container during a fixed period than the amount and nitrogen content in a heap on a manure pad.

During the project period the milk production increased from, in average 9,220 kg ECM to 10,100 kg ECM and the N-efficiency improved. The result of the feeding strategy was that less nitrogen was fed and less N came out of each cow. The redesign of the cowshed and the new manure storage and spreading system increased the utilisation to 91%, which is very close to the expected result in table 2, 93%.

One can discuss if a different feeding strategy would have given a different result in respect of nitrogen efficiency and even better utilization of the nitrogen in the manure. The N-efficiency was considered to be rather high when taking available feed stuffs and the high milk yield in consideration. Other feeding trials have shown that it is possible to reach even better N-efficiency with feed products containing more highly digestible carbohydrates, e.g. sugar beet pulp. These products are mainly used in south Sweden and therefore not easily available for Brogården. Analyses of all milk production data collected at Brogården showed that the N-efficiency increased with higher milk production. A lower milk production level would also have given less income and that was not in line with the overall strategy on Brogården.

7.1.2 Environmental benefits

The major reduction of ammonia losses from Brogården came from storing and spreading of manure. The new slurry system made it possible to apply slurry to growing crop in the springtime. Assuming that 25-50% of the result achieved in the project could by applied to the about 400,000 Swedish dairy cows, the total emission in Sweden would decrease with 2,000 -4,000 tons nitrogen in ammonia per year. This would correspond to 27 – 55% of the total reduction of 7,300 tons, aimed at in the goals set by the government

The feeding strategy used in the project can easily be adopted by any dairy farmer, both with stanchion barn and loose housing. Most likely the nitrogen efficiency in milk production in Sweden is closer to 25% than to 30% and calculations made, by Gustafsson, A. H., has indicated that by 2%-units improved nitrogen efficiency in milk production the total ammonia losses from dairy farms in Sweden would be reduced by 500 – 1700 ton ammonium nitrogen per year, which would correspond to 7 – 23% of the total target 7,300 ton per year.

8 COST SUMMARY

BREAKDOWN OF EXPENDITURE, from October 1, 1999 to September 30, 2003

Item		Amount initially provided for in national currency = Total cost in the Commission's modification 26.9.2001	Amount of expenditure incurred in national currency October, 2003	% *)
1.	Personnel	2 456 500	1 635 369	67%
2.	Travel	156 000	64 226	41%
3.	Outside assistance	5 018 060	4 589 789	91%
4	Durables: total non-depreciated cost	2 021 000	1 909 128	94%
	- Infrastructure sub-total	*192 000*	192 850	100%
	- Equipment sub-total	*1 379 000*	1 278 368	93%
	- Prototypes sub-total	*450 000*	437 910	97%
5.	Consumables	258 500	77 608	30%
6.	Other costs	243 540	245 117	101%
	SUM TOTAL	**10 153 600**	**8 521 237**	**84%**

*) Calculate the percentage by each budget line

The cost for the project was lower than the budget. The original budget was revised twice, the first time 16.2.2000 when the project partners became subcontractors and the second time 28.05.2001 when the cost for the Project Manager was moved from budgetline Personnel to Outside assistance. The total budget for the project was changed. As notified in a letter dated 17.12.2001 the actual cost in the project would be lower than the budget, but no budget modification was regarded necessary, as stated in the letter from 19.12.2002.

The main reasons for under spending are an overestimate of the hours needed to perform the different tasks and some modifications of the work. The following explanations to the lower cost can be found:

1. Late employment of the Project Manager

The Project Manager was not able to join the project until 26.06.2000, that is 9 months after the actual project start. The delay was caused by internal policy matters at SLU, but was solved when the Project Manager was employed by ODAL from 26.06.2000 to 1.8.2001. The delay reduced the cost for salary and overheads by SEK 400,000.

2. Overestimated time for different tasks

Several of the tasks, e.g. Task 1,"Reference measurements", and Task 2, "Analyse of present situation", were carried out using shorter time than planned, the cost was reduced by KSEK 260.

The Management Group considered Task 3, "Definition of Actions" as a part of the work within the Steering Committee and no extra money was allocated to the Committee. The money (KSEK 133) was moved to the Task 6, "Feed planning and feeding". Within Task 4, "Planning of re-design of the building) about KSEK 130 was budgeted for work to be carried out by "Hushållningssällskapet", a advisory and planning bureau in Skara. The invoice was however sent to Husbonden, the owner of Brogården and became part of the rebuilding cost.

Task 7, Management of cow house, included maintenance of a green house, which was never built, as reported in the Interim Report, corresponding to about KSEK 150 less cos. In Task 11, Measurement of ammonia losses at storage and spreading of manure, KSEK 250 was in the budget for spreading slurry with new technique but because no new technique developed during the project time this money was never used. Spreading of slurry with standard, even if was considered to be the best available, technique was regarded as normal farm operation and was paid by the farm.

Total underspending, when taking reallocation of money between tasks, was about KSEK 600.

3. Dissemination

The original budget was revised at an early stage in the project, about KSEK 400 was allocated for seminars for advisers and farmers, arranged by the project. The Information Group considered this to be to much money on an inferior information channel. More money was therefore allocated for a website. The actual cost for this site was however less, about KSEK 300, than budgeted, thanks to a skilled IT-consultant, with agricultural background, and much work carried out by the Information Group. The maintenance and update of the website was done by the Project Manager, as part of the normal job.

Production and distribution of brochures was cheaper than budgeted. The distribution of the Practical advices to almost 19,000 farmers and advisers was budgeted to SEK 100,000 (corresponding to stamp cost), actual cost was SEK 19,278 when distributed as appendix to a agriculture magazine.

By participating in seminars and meetings arranged by the project partners/sub-contractors the cost for these was lower than budget, actual saving is about KSEK 200.

The Management Group has all the time been informed about and approved the lower costs and the reallocation of money between different tasks. They have also expressed their satisfaction with the way the project has been implemented, with the outputs from the project and that set goals have been reached.

The total underspending in the project was KSEK 1,631 where most of the savings came at budgetline Personnel, Travel Consumables.

9 APPENDICES

A. Time schedule
B. Reports from Task 2, Analysis of Present Situation
    B1. Methods for improving nitrogen efficiency in dairy production by dietary protein changes
    B2. Ammonia losses from farm animal buildings
    B3. Ammonia emission from animal manure
    B4. Manure nitrogen in the soil-plant system
C. Report from Reference Year
    C1. Feeding
    C2. Housing
    C3. Manure
D. Layout of the redesigned cow shed
E. "Fakta Lantbruk"
F. Leaflet (in Swedish and English)
G. Practical advises (in Swedish)
H. Final report from HMH (in Swedish)
I. Articles in agricultural magazines and papers
J. Abstracts, papers and handouts from conferences and meetings
K. Layman Report

On CD
- Final Report Technical
- Appendix B, Analyse of Present Situation
- Appendix C, Reports from Reference Year
- Layman Report
- Final Report Financial
- Copy of www.ammoniak.nu
- PowerPoint presentations:
    - CIGR/NJF, Denmark, J-O Sannö
    - Smedjeveckan (in Swedish):
        - Project presentation, J-O Sannö
        - Health and Hygiene, J. Hultgren
        - Ammonia release from the barn, G. Gustafsson
        - Ammonia from storage and spreading. S. Karlsson
        - Mineral balance on farm level, C. Cederberg
        - Economical considerations, J-O Sannö