Deliverable 4.4: Modelling of the environmental performance of best practice and innovative organic pig farms

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All project partners for data collection and feedback

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Contents

Summary

The POWER project aimed to examine the effectiveness of innovations and best practise in achieving improved pig welfare, we also undertook an assessment of their environmental performance. Utilising a life cycle approach, 13 breeding and 9 finishing systems were assessed against four environmental impact categories, including greenhouse gas emissions, air and water pollution and water scarcity. Following data collection on the farms, data was consistency checked and processed through a farm system model, before a life cycle impact assessment was undertaken.

For the breeding systems, there was a large range in values, reflecting the diversity of systems. Enterprises with lower impacts generally comprised outdoor systems, with high sow productivity and less use of external feedstuffs. For the finishing systems, the range in environmental impacts was less, but again influenced by the time pigs were housed for, and the reliance on feed source and also the feeding period. Across all countries, the housing of pigs created additional GHG emissions from manure storage, versus those from pigs at pasture. Reliance on external feed sources also trended towards greater air pollution emissions and water usage, though this may be in part due to reliance on global impact databases for external inputs.

Overall, the LCA indicated lower emissions from productive, outdoor housed breeding and finishing systems, but also lacks the ability to assess non-quantitative aspects of traditional systems that rely on local breeds that are less productive, but provide cultural and other public goods.

1. Introduction

As policies and on-farm measures are developed to enhance organic pig welfare, are there potential trade-offs? The POWER project assessed innovations and systems aimed at delivering improved pig welfare across a number of countries, and as an additional element, the systems were also assessed for their environmental impacts. Utilising a life cycle assessment approach, production and input data was collected on the farms, in addition to the welfare indicators, to enable an assessment of their environmental performance to be undertaken.

2. Materials and methods

The life cycle assessment (LCA) approach was used to assess the environmental sustainability of the pig enterprises within the POWER project. This was undertaken in accordance with ISO norms and (ISO, 2006a; ISO, 2006b). As such, the four primary phases of LCA were observed: (i) goal and scope definition, (ii) life cycle inventory analysis, (iii) life cycle impact assessment, and (iv) interpretation of results.

2.1. Goal

The goal of this LCA study was to undertake an assessment of the environmental performance of the pig enterprises within the project. It was necessary to collect a detailed dataset from each farm. This data was then entered into an Excel based farm system model, which is coupled to a life-cycle impact assessment tool. The data collected included both information related to the pig enterprise, but also any connected enterprises, such as crop enterprises that produce feed for feeding to the pigs. This was especially important as feeds often comprise the largest environmental footprint contribution and costs of the pig enterprise, and therefore a farm specific crop production footprint would enable a more accurate overall estimation of impacts. As part of the data entry process, data consistency checks were undertaken, related to the numbers of pigs and the feeds utilised, to ensure reliability of data.

2.2. Scope

The scope of the assessments were pig farms located in six countries; Austria, Denmark, Germany, Italy, Sweden and Switzerland. Each farm was selected based on a criterion of exhibiting best practise or an innovation that supports improved welfare, as described in previous project deliverables. The boundary for each system was defined to include all process relevant to the pig enterprises on the farm, including both external inputs and within farm processes. The time span for each farm was one production year, with farms visited at least three times to include seasonal aspects of production and animal welfare. Due to the diversity in location and of systems assessed, comparisons between farms should be made with caution.

To enable an environmental assessment beyond greenhouse gases, a total of four impact categories were selected; global warming potential, terrestrial eutrophication, marine eutrophication and water scarcity. These impact categories were further sub-divided to enable a contribution analysis, based on the input type groups.

The functional unit chosen was per kilogram liveweight of pig produced. This was further refined to per kilogram of weaned piglet for the breeding system impacts, or per kilogram finished pig for the finisher systems. As some farm operate breeding and finishing systems, impacts for both categories could be calculated, following allocation.

Allocation of impacts was undertaken as two steps. For many primary inputs, the allocation is direct, including for example, sow and piglet feed can be directly attributed to the breeding system. However, the breeding system also has multiple outputs, including the weaned piglets as a primary product, but also cull sows as a secondary or by product. Furthermore, emissions from this system, such as from manure must also be allocated. This was undertaken via an economic allocation between the two outputs.

2.3. Life cycle inventory analysis

Primary data for all pig enterprises and associated pasture or cropping systems was collected and submitted for each project farm, in the form of a completed Excel data protocol. This data was then processed through a farm system model to generate each life cycle inventory (LCI).

2.3.1. Farm system model

To enable a detailed assessment of the environmental impacts of the selected farms, a model previously developed at FiBL was utilised and significantly developed, to enable assessment of a variety of pig production systems. The assessment model (Schader, 2014) utilises a farm modelling approach to quantify herd structures, crop and forage production, inputs and outputs as well as internal flows within the farm. This is particularly important for organic and other more integrated production philosophies due to the internal flows of materials such as feed and manures between livestock and cropping.

2.3.2. Herd model

Within the pig enterprise, all animals of varying age categories are represented. Within breeding systems, the adult animal (sow), age, weight, productivity, mortality and culling are quantified. Young animals produced from the breeding enterprise are then transferred to intermediary grower and finishing systems before sales or retention as a replacement breeding animal are accounted for. The weights of all animals transferred are quantified, to enable an impact assessment for the two main production phases, breeding and finishing.

2.3.3. LCI additional data

In addition to the primary data and processed primary data values, further data was sometimes required. For this purpose, the extensive ecoinvent LCI database was utilised. Whilst this provides information for a number of additional and background processes, values may still lack specificity for the systems analysed. This could affect the results, in terms of impacts from for example, externally sourced feed, where global or regional values may be used which do not reflect the actual growing conditions of the crop contained within a feed. This remains a problem, when specific information, such as feed ingredient sources are not readily available, and assumptions have to be taken.

3. Results

Results of the LCA are shown by system and begin with an overview of the observed key production parameters, that form part of the inventory. This is followed by the life cycle impact assessment (LCIA) results.

3.1. Productivity and system metrics

Production parameters identify the characteristics and physical performance of each of the systems. These parameters are split by production system into breeding (piglet production up to weaning) and finishing (fattening of weaned piglets through to slaughter).

3.1.1. Breeding system productivity

All of farms with a breeding herd of sows were analysed to identify their performance across a key range of indicators, with results indicated in Table 1. The farms varied in size from an average of 3 to 632 breeding sows, and their average bodyweight was also quite varied, from 200 up to 300kg. The percentage time the sows were housed, was based on their free access to pasture and ranged from housed for 100% of time (with only access to a concrete outdoor run), to fully outdoor. Most systems included at least some housed time.

The number of annual production cycles extended from 1 to 2.25, whilst lactation periods were 42 up to 90 days long. This large range in system size and production intensity resulted in the number of weaned piglets per sow per annum ranging from 6 through to 27. The number of gilts reared varied considerably from 2 to 455 with the number of sows, but also due to the sow culling policy, which varied between 11% and 100% (a single cycle system).

Annual feed use per sow included both concentrates and forages (roughage), and varied from 745kg dry matter (DM) up to almost 2000kg DM per annum. The lowest figure was on a farm with a unique system of a single cycle per year, and the average was 1452kg DM. It should be noted that the sows are likely to have wasted significant quantities of roughage (either provided as silage or as grass at pasture), so actual intake may have varied considerably.

3.1.2. Finishing system productivity

The farms that grow and finish weaned piglets comprised of some farms that also had breeding herds, and some that purchased weaners or weaned piglets from a breeding farm. Finishing system productivity is shown in Table 2, and the enterprises varied in size from 25 to 1800 pigs reared per year. The rearing systems varied considerably between the farms, with some pigs housed 100% of the time with an outdoor run, and others 100% outdoor production.

Productivity was variable, with average daily liveweight gains of up to 0.87kg per day, but the more extensive systems achieving much lower growth rates, and also suffering from greater mortality. The rearing period for weaners was between 42 and 90 days, whilst the finishing phase extended from 84 up to 300 days, which also resulted in very varied feed usage.

Table 1 Breeding system descriptors

Production parameters		AT01	AT02	DE01	DK04	DK05	DK07	IT01	IT02	IT03	IT04	SE01	CH01	CH02
System		**Breeding (piglet production including weaners)**												
Sows														
Liveweight (adult)	kg	268	300	268	300	250	200	200	200	200	200	210	250	240
Housed time	%	25%	100%	75%	13%	13%	13%	50%	50%	50%	0%	75%	75%	75%
Number of sows	#	18	737	47	632	218	109	10	3	12	12	162	199	64
Culled sows	%	20%	12%	11%	62%	53%	25%	20%	100%	17%	17%	43%	40%	47%
Sow mortality	%	6%	2%	4%	10%	12%	13%	0%	0%	0%	0%	14%	3%	2%
Gilts reared per year	#	5	106	7	455	141	41	2	3	2	2	93	86	16
Cycles per annum	#	1.84	2.25	2.16	1.90	1.98	1.86	2.03	1.00	1.70	1.33	2.01	2.10	1.96
Lactation period	days	49	42	48	49	53	51	60	50	60	90	51	42	47
Annual feed use per sow	kg	1071	1428	1992	1578	1677	1737	1441	745	1113	1122	1743	1297	1305
Piglets														
Born per cycle	%	11.4	12.0	15.6	16.4	15.8	17.1	7.0	12.0	5.5	5.5	16.0	13.8	12.1
Mortality	%	5%	25%	31%	21%	17%	33%	14%	9%	18%	18%	28%	20%	15%
Liveweight gain	kg/day	0.22	0.26	0.30	0.22	0.22	0.29	0.13	0.16	0.13	0.09	0.22	0.21	0.21
Piglets reared per sow and year	#	20.2	20.4	23.5	25.4	26.8	22.0	12.2	10.9	7.6	6.0	23.9	23.3	20.3
Weaned piglet per sow	kg LW	263	265	385	331	367	374	122	109	76	60	311	256	243
Weaners														
Housed time	%	100%	100%	100%	50%	100%	0%	0%	0%	0%	0%	75%	100%	100%
Mortality	%	1%	0%	1%	0%	1%	2%	20%	6%	12%	16%	5%	3%	1%
Reared per year	%	342	14399	1054	13303	5566	2342	102	31	82	62	3694	4476	1288
Feeding period	days	42	49	21	35	35	4	90	90	90	90	35	49	39
Piglet and weaner feed use	kg DM/day	1.50	0.44	1.02	1.72	1.37	0.38	1.10	1.10	1.38	1.38	1.35	0.54	0.54
Liveweight gain	kg/day	0.45	0.35	0.46	0.56	0.61	0.25	0.45	0.45	0.45	0.45	0.57	0.45	0.32
Pig enterprise														
Feed self-sufficiency	%	74%	20%	89%	79%	17%	20%	86%	23%	75%	36%	78%	13%	14%

Table 2 Production parameters - Finishing systems

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Production parameters		AT01	IT01	IT02	IT03	IT04	AT03	AT04	DK06*	SE02
System		Breeding & finishing					Finishing only			
Weaners										
Housed time	%	100%	0%	0%	0%	0%			0%	
Mortality	%	1%	20%	6%	12%	16%			2%	
Reared per year	#	342	102	31	82	62			1335	
Feeding period	days	42	90	90	90	90			42	
Piglet and weaner feed use	kg DM/day	1.30	1.10	1.10	1.38	1.38			1.82	
Liveweight gain	kg/day	0.45	0.45	0.45	0.45	0.45			0.64	
Finishers										
Housed time	%	100%	0%	0%	75%	0%	2%	0%	0%	100%
Mortality	%	1%	1%	1%	1%	1%	1%	5%	1%	1%
Reared per year	#	330	98	25	78	58	900	300	1300	1800
Feeding period	days	130	300	120	250	250	130	130	84	115
Piglet and weaner feed use	kg DM/day	1.75	2.75	2.75	2.26	2.51	2.65	2.97	2.83	2.53
Liveweight gain	kg/day	0.68	0.27	0.58	0.27	0.27	0.58	0.58	0.87	0.75
Pig enterprise										
Feed self-sufficiency	%	74%	86%	23%	75%	36%	89%	73%	8%	83%

* DK06 buys weaned piglets

3.2. Lifecycle Impact Assessment (LCIA)

After constructing the pig herd structure and inputting the feed rations for each class of animal and production phase, the lifecycle inventory was compiled ready for the lifecycle impact analysis, to quantify the environmental impacts and contribution analysis. Results are presented for four main impact categories, to identify the main impacts of the various pig systems for a range of environmental impacts:

- Global Warming Potential (GHGs in CO_2 equivalents) – global warming effect
- Terrestrial eutrophication (molc N eq) – air pollution
- Marine eutrophication (kg N eq) – water pollution
- Water footprint (regionalised m3) – water usage

3.2.1. Breeding phase

The breeding phase impacts are quantified in the following figures, and the functional unit for all impact metrics is per kilogram of weaned piglet (with most farms weaning at ~13kg liveweight).

3.2.1.1. Global Warming Potential (GHGs)

Figure 1 indicates a large range in GHG emissions between the farms, ranging from 3.4 to 9.8kg CO_2e per kg weaned piglet. The chart shows that farms with less emissions from manure storage (due to outdoor production), usually have lower total emissions. Feed is the primary or second largest impact contributor, and as the farms varied in their level of self-sufficiency the external and internal feed impact contribution is varied, however lower annual productivity will cause an increase in emissions from feed per kg of piglet produced.

3.2.1.2. Terrestrial eutrophication

Figure 2 indicates the level of terrestrial eutrophication or air pollution, and shows a six-fold variation in impacts between the farms. The main contributor to this impact category comes from feed production, whether externally sourced or home grown. Therefore, the greater the total feed use per kg of weaned piglet, the higher the impact on air pollution in the form of various nitrogen compounds.

3.2.1.3. Marine eutrophication

Figure 3 indicates the potential nitrogen losses to water, causing marine eutrophication. Many of the farms are at a similar level, with a few at higher emission levels, mainly due to lower productivity with the speciality breed sows. Across all the farms, it can be seen that feed usage, related to its production, is the by far the greatest contributor to emissions.

3.2.1.4. Water footprint

Figure 4 indicates water consumption by the farms, adjusted for regional availability. The relative height of the chart components, indicates external feed to be a primary contributor to water use, whilst homegrown feed has minimal impacts. This may in part be due to the use of external feed LCA inventory data, but also reflects the greater water use impacts related to high protein feeds, which often dominate externally sourced feed usage.

Figure 1 Greenhouse gases (GWP100) per kg weaned piglet (~13kg)

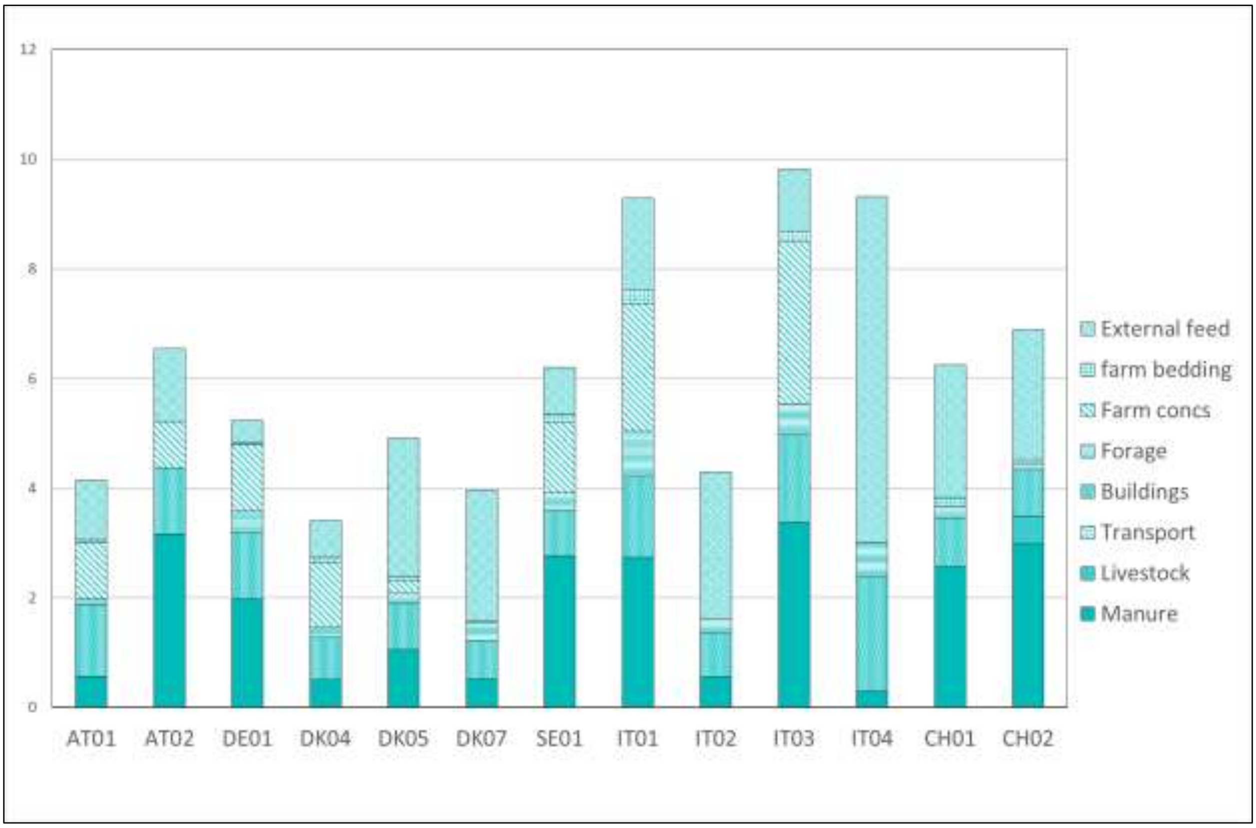


Figure 2 Terrestrial eutrophication (molc N eq) per kg weaned piglet

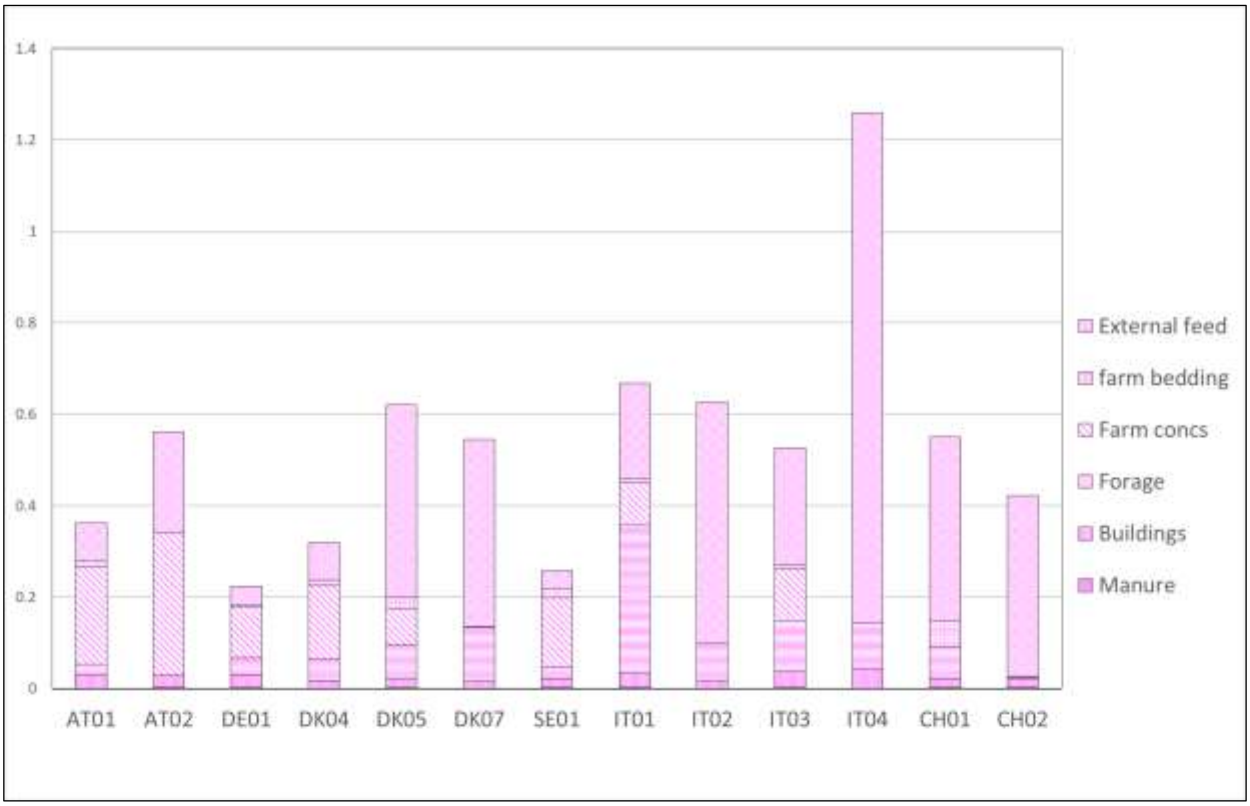


Figure 3 Marine eutrophication (kg N eq) per kg weaned piglet

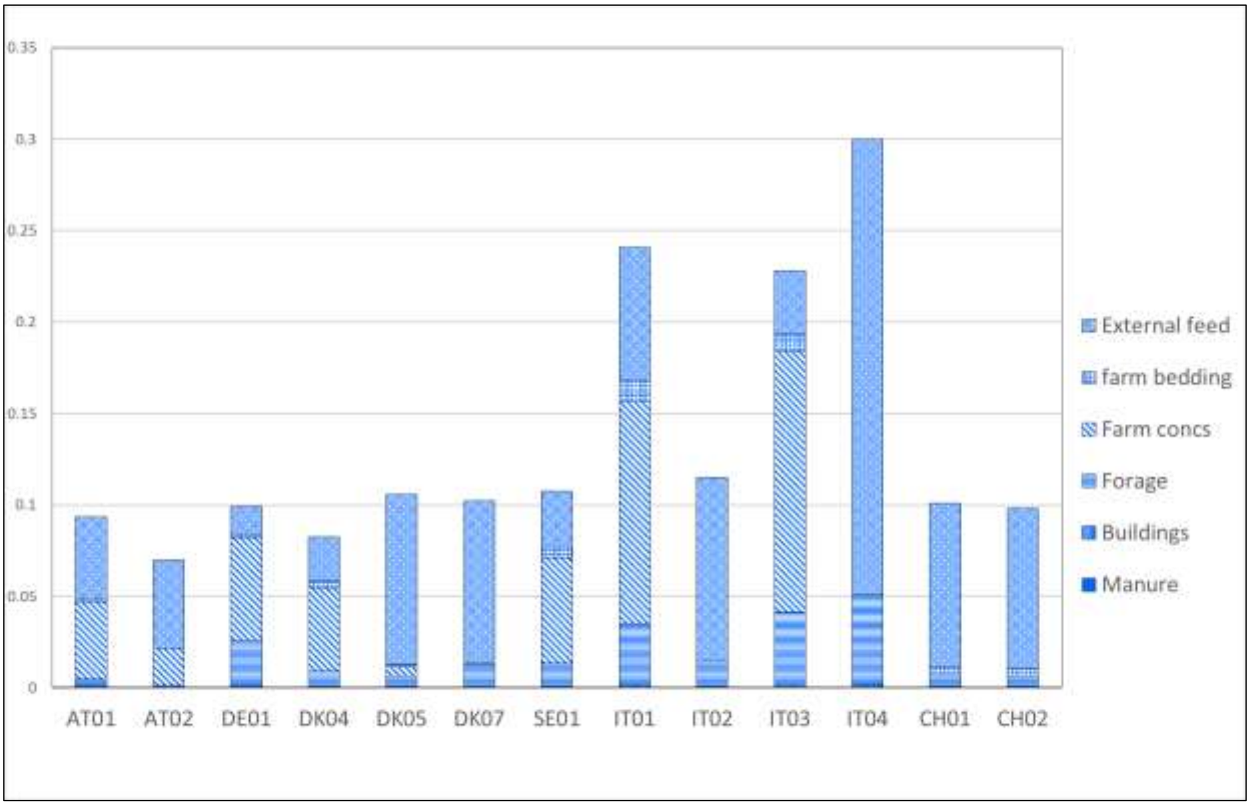
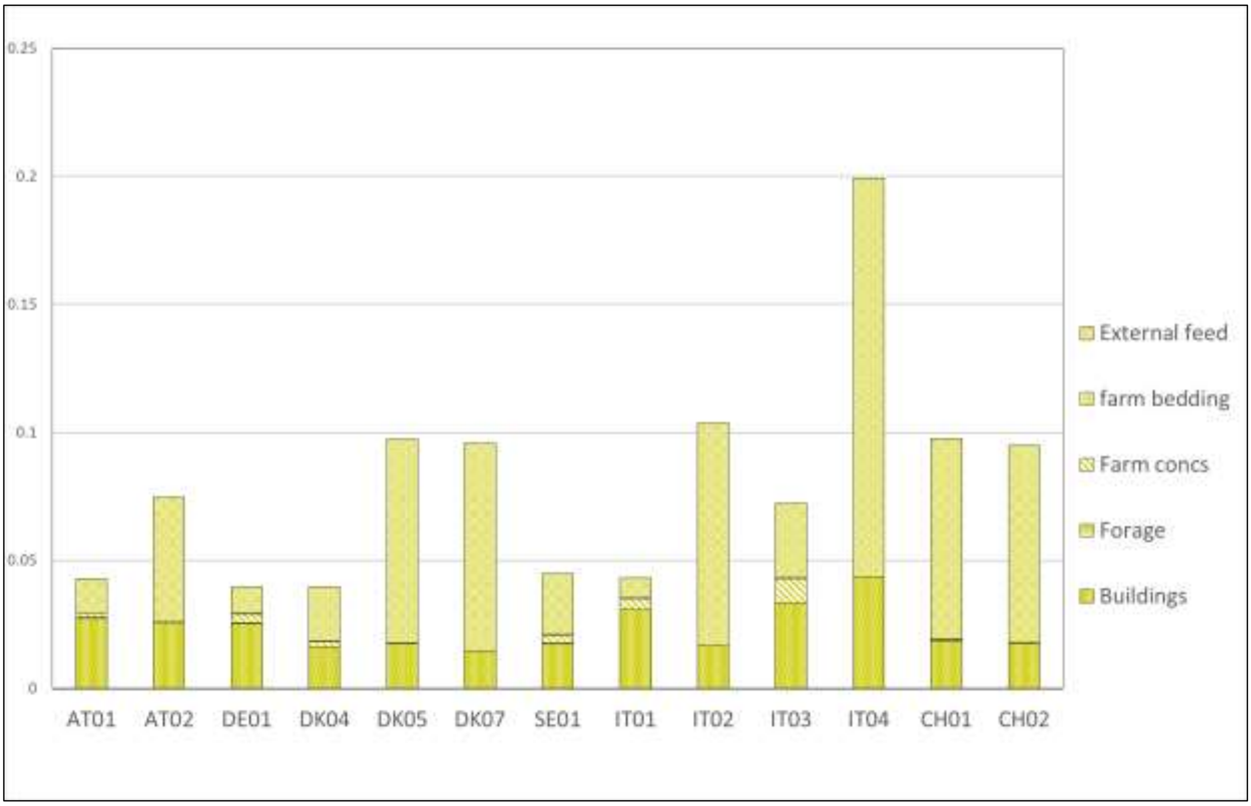


Figure 4 Water footprint (regionalised) (m3) per kg weaned piglet



3.2.2. Finishing pigs (including breeding and finishers)

The finishing phase impacts are quantified in the following figures, and the functional unit for all impact metrics is per kilogram of finished pig (with a typical weight ~110kg liveweight). The finished pig emissions include the piglet, weaner and finisher life phases, meaning data is comparable between finisher only and breeder/finisher systems. However, for the farms that purchase weaners, there is a purchased livestock segment, that includes their embedded emissions as a single contribution (rather than split into feed, manure etc, as for the breeder finisher farms). Where possible the embedded emissions were taken from the actual supplying farm (if they were part of the POWER project), otherwise, the data was assumed from other breeding farms in the project in the same country.

3.2.2.1. Global Warming Potential (GHGs)

Figure 5 indicates a smaller range in GHG emissions between the farms than for the breeding stage only, with impact values ranging from 2.9 to 4.6kg CO_2e per kg liveweight of finished pig. The chart shows that farms with indoor finishing have higher emissions than the outdoor systems due to losses during manure storage. Feed is also a large GHG impact contributor. For the farms that purchase weaners or piglets, these embedded emissions also contribute a significant proportion of the total GHG impacts, reflecting the importance of low emission piglet production.

3.2.2.2. Terrestrial eutrophication

Figure 6 indicates the level of terrestrial eutrophication or air pollution in the form of various nitrogen compounds, and also shows smaller variation than for the breeding farms. Values range from 0.145 to 0.54 molecules of nitrogen equivalents. The main contributor to this impact category comes from feed production, especially related to external feed production, related to fertilisation of the crops.

3.2.2.3. Marine eutrophication

Figure 7 indicates the potential nitrogen losses to water, causing marine eutrophication. As with the breeding farms, many of the finishing pig values are at a similar level. However, a few are at a higher emission level, mainly due to lower productivity with the speciality breed sows. Across all the farms, it can be seen that feed usage, related to its production, is the by far the greatest contributor to emissions.

3.2.2.4. Water footprint

Figure 8 indicates water consumption by the farms, adjusted for regional availability. The relative height of the chart components, indicates external feed to be the main contributor to water use, whilst homegrown feed has minimal impacts. This may also be in part due to the use of an external feed LCA inventory database, but also reflects the greater water use impacts related to high protein feeds, which often dominate externally sourced feed usage.

In the following charts all farms include impacts from breeding and finishing, but those that purchase weaners have a single "livestock" category for embedded emissions, the others show their embedded emissions across all categories.

Figure 5 Greenhouse gases (GWP100) per kg finished pig

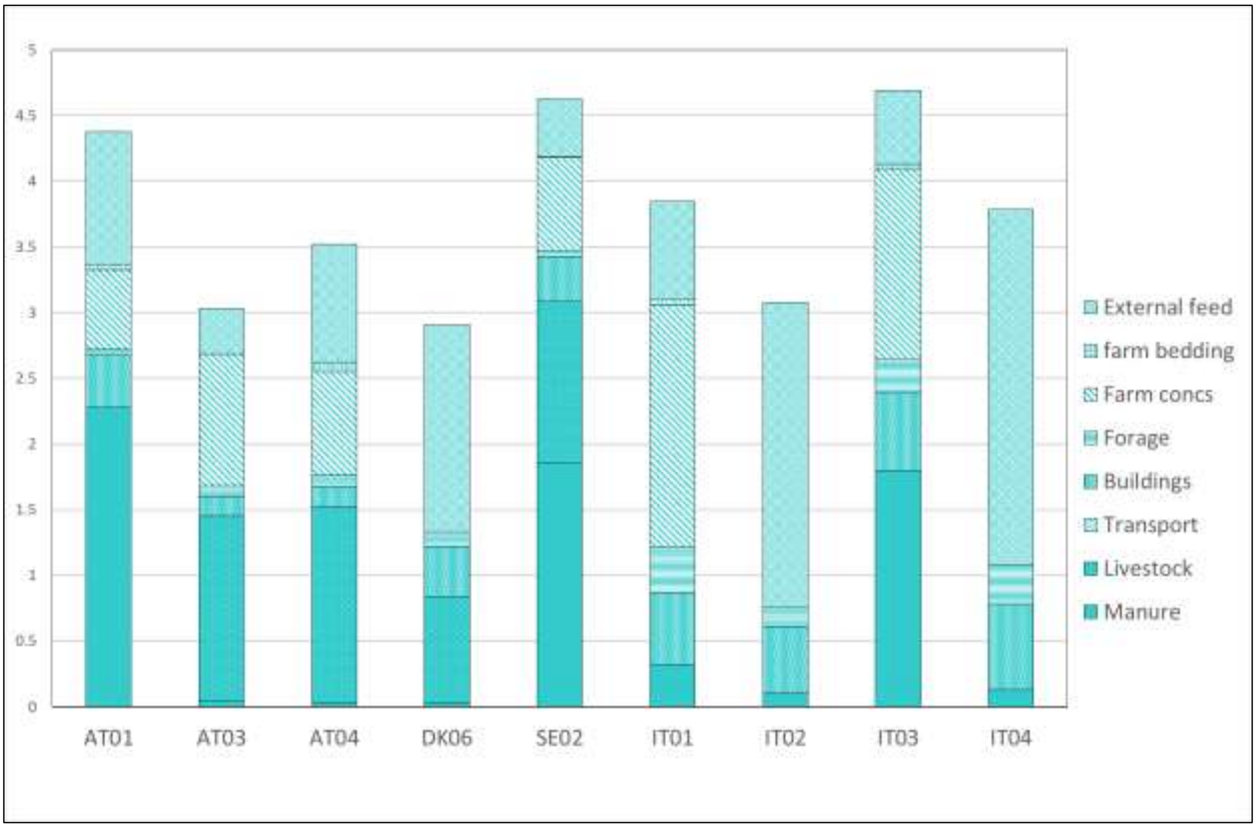


Figure 6 Terrestrial eutrophication (molc N eq) per kg finished

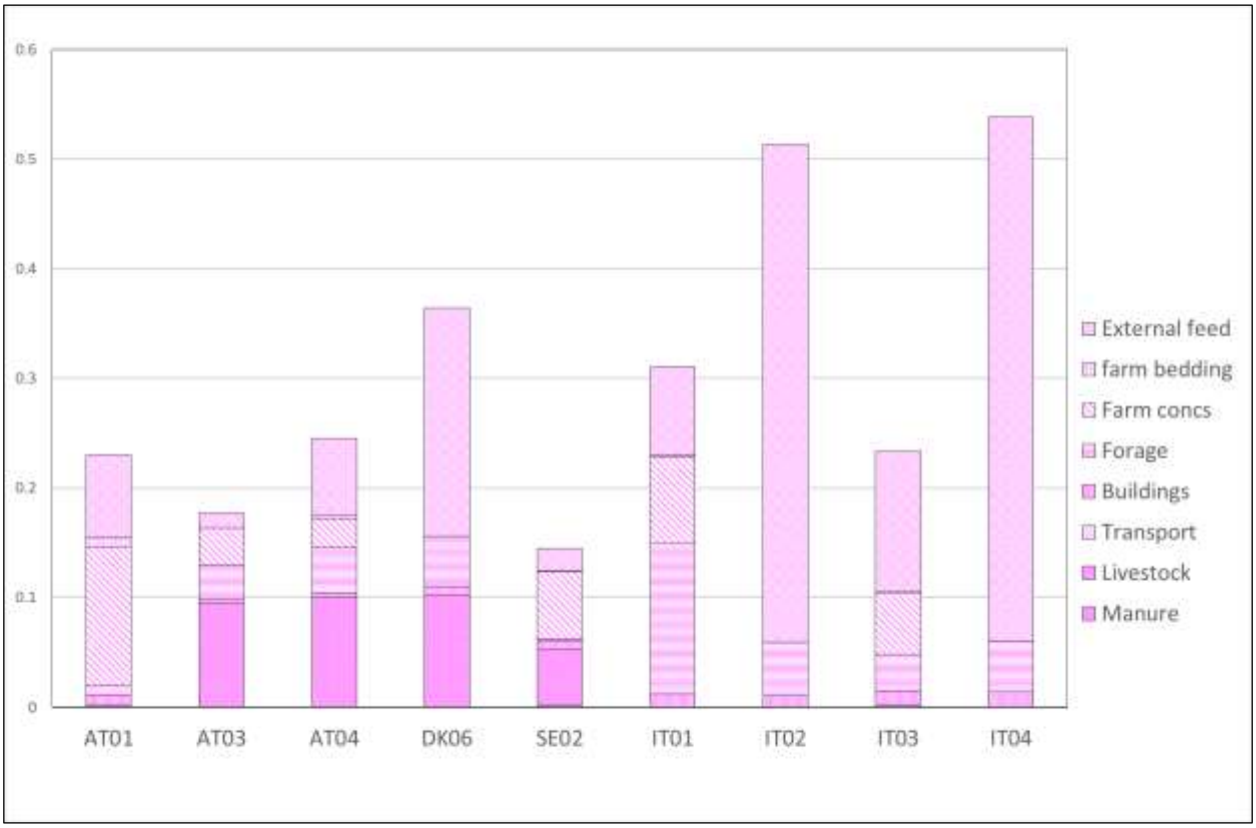


Figure 7 Marine eutrophication (kg N eq) per kg finished

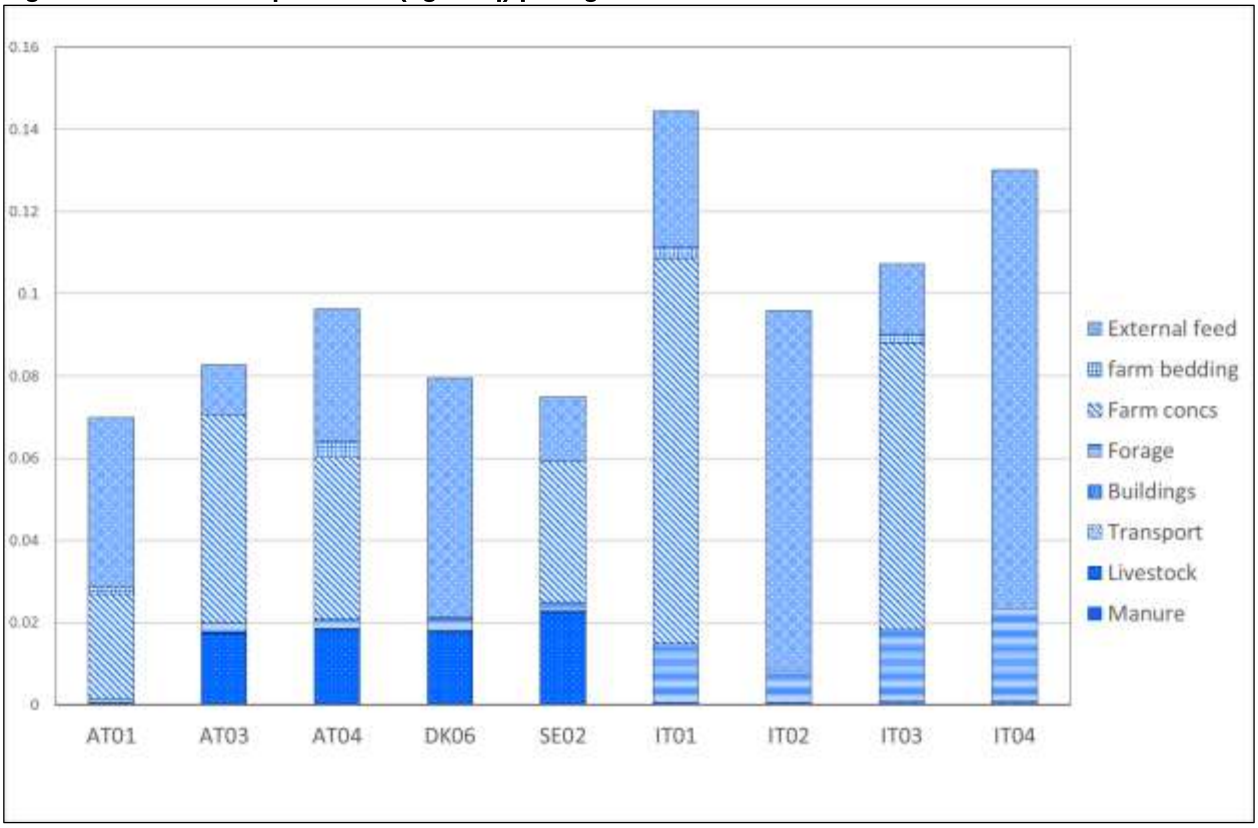
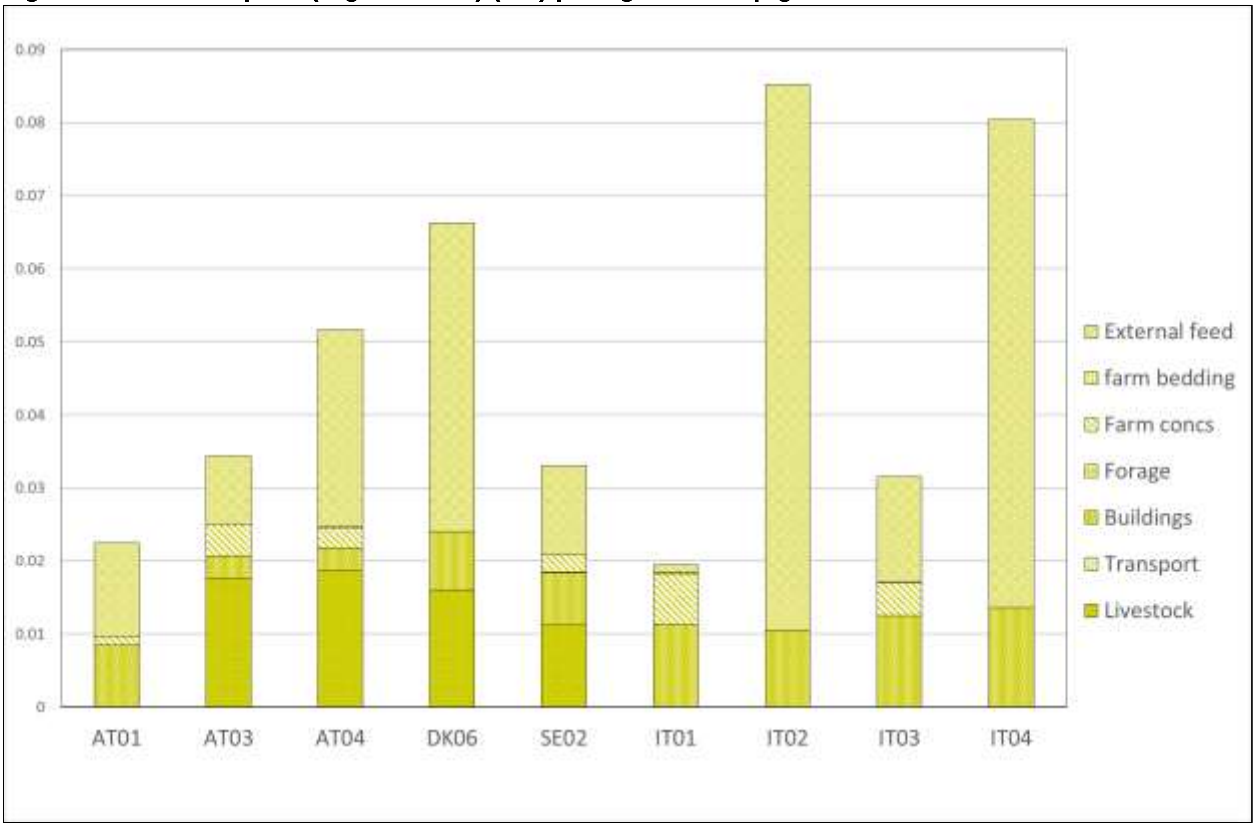


Figure 8 Water footprint (regionalised) (m3) per kg finished pig



4. Discussion & Conclusions

The results of the LCA show a wide range in impact values across the different systems. This reflects the diversity of production methods studied in the project, ranging from breeder/finishing systems of a few sows, through to large scale farms fattening thousands of pigs per year. All the results are presented as per kilogram liveweight of either weaned piglet or finished pig.

For the breeding system enterprises, the largest impacts were a result of manure storage emissions and feed usage. The farms with mainly outdoor production generally had lower emissions overall, especially for GHGs. The use of homegrown feed also played a role in lower emissions, especially in relation to air pollution and water consumption.

For the finishing pig systems, the range in values between the systems was less pronounced, but the largest impacts were also related to manure storage and external feed usage. For the finishing systems, the impacts of the piglet stage also play a key role in the finished pig's impacts.

The results tend to favour the systems that have the highest productivity, and this reflects the choice of functional unit of per kilogram pig. This means that greater productivity can outweigh greater use of inputs, such as external (or homegrown) feeds. An alternative functional unit would be impact values per hectare. However, as there is great variability in the use of land by the different systems, this would result in quite erratic values. The difficulty lies in defining the area utilised by the pig enterprises, especially when the pigs are housed with a concrete outdoor run.

Within the project, the focus was on creating more resilient systems that improved welfare for the pigs. Whilst every effort was made to record pig enterprise data accurately, we found it was difficult for the data enumerators to simultaneously record welfare and productivity data. For future projects, consistency checks in the data collection system may help to avoid inconsistencies between, for example, feed rations and feed production /purchases, or pigs sold and sow productivity.

Overall, the analysis indicates that outdoor and productive pig enterprises have a low environmental impact, whilst improving welfare. Emissions and impacts on water use also seemed to be lower for enterprises that utilised homegrown feeds, possibly due to circularity of nutrient flows, rather than the introduction of potentially excess nutrients through externally sourced feeds. However, LCA, and especially the per kilogram of pig functional unit, may not fully reflect the environmental impacts of production at the local scale. Furthermore, it may also not reflect the additional cultural and public goods delivered by specialist, traditional breed production, that typically uses less productive breeds, under extensive production methods.

5. Acknowledgment

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6. References

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