NEWSLETTER LIFE MEGA PROJECT
LIFE18 ENV/IT/000200
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Life-MEGA

Smart computing system to monitor and abate the indoor concentrations of NH3, CH4 and PM in pig farms

UPDATES:

LCA study

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Project

The LIFE MEGA project, funded by the LIFE program of the European Union, aims to improve air quality in pig farms through the adoption of two different air treatment technologies: a dry and a wet acid scrubber.

This newsletter focuses on the work carried out on the quantification of the environmental footprint of pig production, with a specific focus on housing emissions. Life Cycle Assessment (LCA) was used to quantify the environmental impact of pig production under "standard" production context and compare it with production when implementing the two air treatment technologies aimed at abating pollutant emissions, i) wet scrubber; ii) dry scrubber. In general terms, a potential emission reduction by incorporating these technologies into the farm could help to improve the sustainability of the pig production sector.

The environmental impact was quantified both for one Spanish transition farm and for the two Italian fattening farms.

LCA methodology

LCA is an internationally recognized methodology, regulated by ISO standards (ISO 14040 2006; ISO 14044 2018), that aims to analyse products, processes, or activities from an environmental perspective throughout their entire life cycle, or even part of it. This methodology considers all the inputs (resources and energy consumed), and outputs (emissions and wastes) generated. In summary, an LCA study includes all aspects that could potentially affect human health, ecosystem quality and depletion of resources.

An LCA study includes 4 phases: 1) Goal and scope definition, 2) Life Cycle Inventory, 3) Life Cycle Impact Assessment, and 4) Interpretation of the results.

Goal and scope definition

The goal of the LCA study was to quantify the environmental footprint of a pig production system, with a specific focus on air cleaning technologies to reduce housing emissions. The analysis was carried out with a cradle-to-farm gate approach, the functional unit adopted was 1 kg of live weight produced.

To highlight the difference between a traditional production system and one with the use of air treatment technologies, two scenarios were compared (baseline Vs. alternative). The baseline scenario corresponds to a representative transition pig farm in Spain and two fattening pig farms in Italy. The alternative correspond to the same system but with installed the two air cleaning scrubbers.

Life Cycle Inventory

As for Italy, the analysed farms are in Lombardy, Northern Italy. These are two intensive closed cycle (or farrowing-to-finishing) farms, meaning that produce piglets and raise them up to market weight. Specifically, heavy pigs for PDO dry-cured ham consortia are produced.

As for Spain, the analysed farm is in Santa Eulalia de Riuprimer, Catalonia. The farm in Spain includes the transition stage, thus pigs from post-weaning up to 30-40 days of life, when they move on to a new stage (a fattening farm).

The final inventory for the analysis consisted of collected data referring to the farm productive performance (stocking rate, production rate, etc.), to the consumption of the different resources (e.g., feed, water, energy use, cleaning products, etc.) as well as the waste (plastic, water, etc.) and emissions produced (enteric fermentation, manure management). Primary data regarding farming activities were collected by means of questionnaires provided to farmers regarding inputs and outputs of production processes. Converserly, secondary data regarding air pollutants emissions were estimated using different established models available in the literature, such as IPCC and EEA guidelines.

Regarding the dry scrubber, the following information was collected: filter material, working time, energy consumption. The same applies to the wet scrubber scenario where water and citric acid consumption, ammonia abatement (and consequently nitrogen recovered in the solution) were also collected.

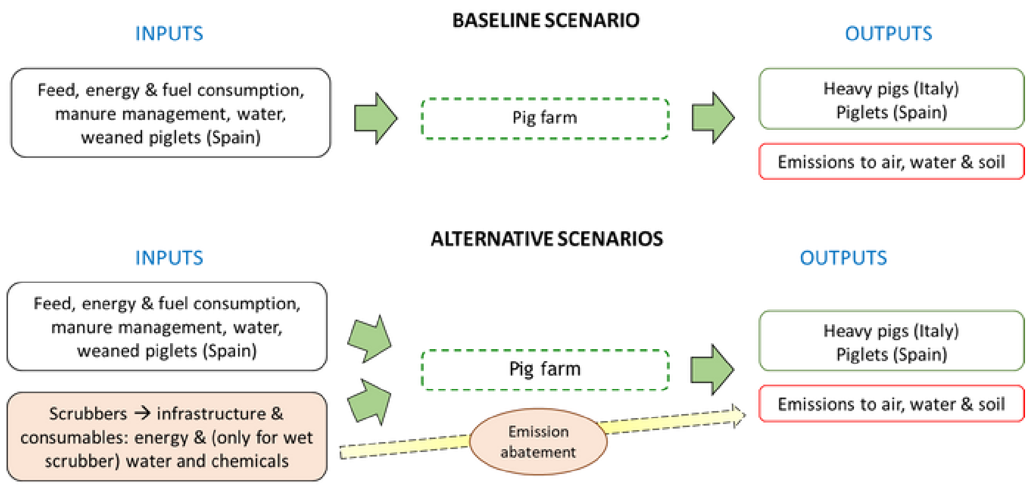

Fig. 1 LCA systems boundaries

Results of the Italian baseline scenario

The two Italian fattening farms analyzed show different results in absolute terms but are aligned in relative terms. In fact, the impact per kg of live weight is somewhat variable between the two mainly due to the different feeds used, and secondly to the different management of the breeding phases and growing performances. For climate change, particulate matter formation and terrestrial eutrophication the main contribution is instead given by pollutant emissions on farm.

Impact categories	Units	Farm emissions (enteric and manure management)	Feed	Diesel	Electricity, gas & other	Water
Climate change	kg CO_2 eq	3.25E+00	2.48E+00	2.29E-01	6.92E-02	1.53E-02
Ozone depletion	kg CFC11 eq	0.00E+00	1.02E-07	3.75E-08	9.35E-09	1.02E-09
Ionising radiation	kBq U-235 eq	0.00E+00	5.51E-02	1.34E-02	9.39E-03	5.45E-03
Photochemical ozone formation	kg NMVOC eq	2.98E-03	5.83E-03	2.20E-03	1.55E-04	5.08E-05
Particulate matter	disease inc.	7.21E-07	1.36E-07	9.44E-09	1.38E-09	8.19E-10
Human toxicity, non-cancer	CTUh	4.89E-09	4.53E-08	7.72E-09	6.94E-10	9.03E-10
Human toxicity, cancer	CTUh	0.00E+00	1.54E-09	2.04E-10	2.56E-11	6.41E-11
Acidification	mol H+ eq	3.93E-03	1.81E-02	1.94E-03	3.35E-04	8.50E-05
Eutrophication, freshwater	kg P eq	0.00E+00	6.03E-04	3.39E-05	1.76E-05	1.10E-05
Eutrophication, marine	kg N eq	3.02E-03	1.87E-02	7.24E-04	4.94E-05	1.64E-05
Eutrophication, terrestrial	mol N eq	2.74E-01	7.31E-02	7.90E-03	5.51E-04	1.56E-04
Ecotoxicity, freshwater	CTUe	4.44E+00	6.37E+01	3.65E+00	8.46E-01	2.77E-01
Land use	Pt	0.00E+00	2.06E+02	3.60E+00	3.49E-01	6.21E-02
Water use	m^3 depriv.	0.00E+00	1.65E+01	1.84E-02	4.65E-02	1.99E+00
Resource use, fossils	MJ	0.00E+00	9.93E+00	2.92E+00	1.04E+00	2.62E-01
Resource use, minerals and metals	kg Sb eq	0.00E+00	9.77E-06	2.43E-06	6.71E-07	7.55E-08

Fig. 2 Environmental results and hotspots for the baseline scenario of the first Italian farm

Impact categories	Units	Farm emissions (enteric and manure management)	Feed	Diesel	Electricity, gas & other	Water
Climate change	kg CO_2 eq	2.57E+00	2.07E+00	1.48E-01	1.50E-01	1.53E-02
Ozone depletion	kg CFC11 eq	0.00E+00	1.15E-07	3.37E-08	2.02E-08	1.02E-09
Ionising radiation	kBq U-235 eq	0.00E+00	6.44E-02	9.12E-03	2.03E-02	5.45E-03
Photochemical ozone formation	kg NMVOC eq	2.40E-03	5.67E-03	1.83E-03	3.36E-04	5.08E-05
Particulate matter	disease inc.	5.65E-07	1.96E-07	2.32E-09	2.99E-09	8.19E-10
Human toxicity, non-cancer	CTUh	3.87E-09	3.02E-08	1.24E-09	1.50E-09	9.03E-10
Human toxicity, cancer	CTUh	0.00E+00	1.17E-09	1.36E-11	5.54E-11	6.41E-11
Acidification	mol H+ eq	3.03E-03	2.80E-02	1.48E-03	7.24E-04	8.50E-05
Eutrophication, freshwater	kg P eq	0.00E+00	1.69E-03	1.57E-06	3.80E-05	1.10E-05
Eutrophication, marine	kg N eq	2.33E-03	1.07E-02	6.50E-04	1.07E-04	1.64E-05
Eutrophication, terrestrial	mol N eq	2.11E-01	1.19E-01	7.13E-03	1.19E-03	1.56E-04
Ecotoxicity, freshwater	CTUe	3.43E+00	7.08E+01	1.08E+00	1.83E+00	2.77E-01
Land use	Pt	0.00E+00	1.94E+02	2.59E-01	7.54E-01	6.21E-02
Water use	m^3 depriv.	0.00E+00	4.25E+01	3.18E-04	1.01E-01	1.99E+00
Resource use, fossils	MJ	0.00E+00	9.16E+00	2.03E+00	2.25E+00	2.62E-01
Resource use, minerals and metals	kg Sb eq	0.00E+00	7.43E-06	2.65E-08	1.45E-06	7.55E-08

Fig. 3 Environmental results and hotspots for the baseline scenario of the second Italian farm

Results of the Spanish baseline scenario

Main process contribution in the Spanish farm comes from three processes: purchasing of weaned piglets, emissions at farm and compound feed. Main differences between the Italian and the Spanish farm comes from the difference in the farm stages considered (transition for Spain, fattening for Italy).

Impact from weaned piglets, which were purchased at farms in the region, included all the necessary processes for the rearing of the animals up to the weaning stage. Therefore, weaned piglets impact carried the weight from the compound feed impact (thus, crops used on the feed for the sows), farm emissions from enteric fermentation and manure storage, energy and water consumption and infrastructure. The impact from the weaned piglets contributed with over a 5% on all impact categories.

Impact categories	Units	Farm (enteric fermentation+manure management emissions)	Farm 0, weaned piglets	Compound feed	Diesel	Electricity, gas &oil	Water	Transport	Carcasses Incinerated
Climate change	kg CO_2 eq	4,0E+05	2,0E+06	1,2E+06	1,7E+05	2,1E+03	1,1E+03	1,5E+04	2,1E+05
Ozone depletion	kg CFC11 eq	0,0E+00	1,2E-01	1,0E-01	2,7E-02	6,3E-04	2,2E-04	3,0E-03	1,6E-02
Ionising radiation	kBq U-235 eq	0,0E+00	4,0E+05	1,3E+05	9,8E+03	6,1E+03	1,6E+03	1,3E+03	4,4E+03
Photochemical ozone formation	kg NMVOC eq	2,4E+02	4,1E+03	4,5E+03	1,6E+03	3,2E+00	2,9E+00	8,6E+01	3,8E+02
Particulate matter	disease inc.	7,7E-02	3,1E-01	6,9E-02	6,3E-03	1,0E-04	6,6E-05	1,4E-03	4,7E-03
Human toxicity, non-cancer	CTUh	5,8E-04	3,6E-02	5,3E-02	5,7E-03	3,4E-05	2,2E-05	2,9E-04	5,2E-03
Human toxicity, cancer	CTUh	0,0E+00	1,3E-03	1,2E-03	1,3E-04	1,1E-06	1,1E-06	2,0E-05	1,4E-04
Acidification	mol H+ eq	2,0E+02	4,5E+04	9,0E+03	1,4E+03	1,4E+01	8,4E+00	8,0E+01	5,2E+02
Eutrophication, freshwater	kg P eq	0,0E+00	3,3E+02	3,3E+02	2,8E+01	3,4E-01	4,3E-01	2,5E+00	7,2E+01
Eutrophication, marine	kg N eq	2,5E+02	1,1E+04	8,9E+03	5,2E+02	1,4E+00	1,1E+00	2,4E+01	8,4E+01
Eutrophication, terrestrial	mol N eq	9,2E+03	2,0E+05	3,1E+04	5,7E+03	4,8E+01	1,8E+01	2,7E+02	9,1E+02
Ecotoxicity, freshwater	CTUe	3,6E+05	4,7E+07	6,9E+07	2,8E+06	4,2E+04	2,2E+04	2,3E+05	5,1E+06
Land use	Pt	2,8E+05	1,5E+08	1,2E+08	2,7E+06	4,0E+03	6,2E+03	1,2E+05	2,8E+05
Water use	m^3 depriv.	0,0E+00	2,6E+06	1,8E+07	1,2E+04	2,7E+03	5,9E+05	8,9E+02	2,6E+04
Resource use, fossils	MJ	0,0E+00	1,4E+07	1,1E+07	2,1E+06	1,3E+05	3,9E+04	2,2E+05	8,3E+05
Resource use, minerals and metals	kg Sb eq	0,0E+00	3,0E+00	2,6E+01	8,0E+00	2,7E-02	1,9E-02	3,4E-01	6,8E-01

Fig. 4 Environmental results and hotspots for the baseline scenario of the Spanish transition farm

Results of the Italian alternative scenarios: dry Vs. wet scrubber

Overall the dry scrubber has more positive environmental performances than the wet scrubber. This is for three reasons:

- the impact categories positively influenced in the dry scrubber scenario are always more than those in the wet scrubber scenario. In fact, the latter has led to reductions in impact always and only for two categories, namely particulate matter formation potential and terrestrial eutrophication, while the dry scrubber has led to improvements, albeit small, also for other categories including climate change, acidification, marine eutrophication and freshwater ecotoxicity.
- For the two categories improved also by the wet scrubber, the dry scrubber has in any case achieved higher mitigations: for PM formation a maximum of -25% and -18% in farms A and B against -14% and -10% in the wet scrubber scenario; and for terrestrial eutrophication a maximum of -24% and 16% in farms A and B versus -18% and -12% in the wet scrubber scenario. Fig. 5 shows the results compared with the baseline scenario of the first farm considered.
- Impact categories are not influenced by the emissions abatement given by the machinery. In the case of wet scrubber scenario there are non-negligible increases in the impact, which in the worst case (Farm A, maximum emissions reduction scenario) are even greater than 50% for ozone depletion, ionizing radiation, fossil resource use and even greater of 100% for mineral and metal resource use. In the case of the dry scrubber, however, these increases are very limited, always less than 5% across categories, farms and efficiencies scenarios.

Impact Category	Units	Maximum abatement efficiency		Median abatement efficiency	
		Wet scrubber	Dry scrubber	Wet scrubber	Dry scrubber
		Impact change (%)	Impact change (%)	Impact change (%)	Impact change (%)
Climate change	kg CO_2 eq	13.85%	-0.22%	5.77%	0.17%
Ozone depletion	kg CFC11 eq	67.16%	1.69%	27.96%	1.69%
Ionising radiation	kBq U-235 eq	52.37%	3.06%	24.75%	3.06%
Photochemical ozone formation	kg NMVOC eq	25.11%	0.49%	10.18%	0.49%
Particulate matter	disease inc.	-14.22%	-25.16%	-5.03%	-7.53%
Human toxicity, non-cancer	CTUh	61.92%	0.41%	24.01%	0.57%
Human toxicity, cancer	CTUh	47.72%	1.00%	25.76%	1.00%
Acidification	mol H+ eq	25.43%	-4.37%	10.26%	-0.92%
Eutrophication, freshwater	kg P eq	41.95%	0.98%	17.16%	0.98%
Eutrophication, marine	kg N eq	3.41%	-4.05%	1.40%	-1.18%
Eutrophication, terrestrial	mol N eq	-18.17%	-23.66%	-6.75%	-7.19%
Ecotoxicity, freshwater	CTUe	48.96%	-1.30%	19.13%	-0.01%
Land use	Pt	4.29%	0.05%	1.70%	0.05%
Water use	m^3 depriv.	6.54%	0.07%	2.58%	0.07%
Resource use, fossils	MJ	62.35%	2.13%	26.89%	2.13%
Resource use, minerals and metals	kg Sb eq	146.48%	3.69%	58.43%	3.69%

Fig. 5 Environmental impact results for Wet scrubber and Dry scrubber expressed as impact change with respect to the baseline scenario of the first Italian farm considered

Results of the Spanish alternative scenarios: dry Vs. wet scrubber

Wet scrubber was more efficient reducing ammonia emissions compared to the dry scrubber in the Spanish context, which was related to an improvement in different impact categories. Particulate matter and terrestrial eutrophication reduced the impact by 9.66 and 1.80% considering the maximum emissions abatement scenario. Also, marine eutrophication, but to a lesser extent (0.16%). Ammonia emissions reduction had also an impact on cancer human toxicity, acidification and freshwater ecotoxicity, but this was overwritten by the increase in impact to these categories coming from the consumables used for the wet scrubber operation, and specifically citric acid consumption. Similar results are achieved considering the median emissions abatement scenario.

While reducing impact for the abovementioned categories, both wet and dry scrubbers add impact over the baseline scenario for all remaining categories. This is because the implementation of these technologies involves extra energy (electricity), infrastructure and, in the case of wet scrubber, also consumables (citric acid and water). This added impact was greater in the case of wet scrubber than in the dry scrubber. (*Continues...*)

(...) The dry scrubber showed less efficiency in the removal of ammonia, but it also added less impact to the overall results for each indicator (<1% contribution to all indicators). Moreover, results obtained showed a reduction in methane emission in the dry scrubber scenario, which had an effect in considerably reducing potential impact to climate change.

Impact Category	Units	Maximum abatement efficiency		Median abatement efficiency	
		Wet scrubber	Dry scrubber	Wet scrubber	Dry scrubber
		Impact change (%)	Impact change (%)	Impact change (%)	Impact change (%)
Climate change	kg CO_2 eq	1,42%	-3,68%	0,80%	-2,50%
Ozone depletion	kg CFC11 eq	2,71%	0,16%	1,47%	0,16%
Ionising radiation	kBq U-235 eq	1,37%	0,44%	0,75%	0,44%
Photochemical ozone formation	kg NMVOC eq	1,84%	-0,26%	1,03%	-0,13%
Particulate matter	disease inc.	-9,66%	-7,98%	-6,86%	-6,79%
Human toxicity, non-cancer	CTUh	2,57%	-0,03%	1,41%	0,04%
Human toxicity, cancer	CTUh	4,66%	0,39%	3,88%	0,39%
Acidification	mol H+ eq	0,70%	-0,03%	0,39%	0,01%
Eutrophication, freshwater	kg P eq	2,59%	0,25%	1,46%	0,25%
Eutrophication, marine	kg N eq	-0,16%	-0,41%	-0,07%	-0,29%
Eutrophication, terrestrial	mol N eq	-1,80%	-1,29%	-0,95%	-0,92%
Ecotoxicity, freshwater	CTUe	1,95%	0,04%	1,08%	0,07%
Land use	Pt	0,24%	0,01%	0,13%	0,01%
Water use	m^3 depriv.	0,45%	0,01%	0,24%	0,01%
Resource use, fossils	MJ	2,49%	0,30%	1,40%	0,30%
Resource use, minerals and metals	kg Sb eq	3,61%	0,71%	2,04%	0,71%

Fig. 6 Environmental impact results for Wet scrubber and Dry scrubber expressed as impact change with respect to the baseline scenario

Discussion and conclusions

Both tested technologies showed their potential to reduce emissions in the pig housing stage, which had an effect on all those categories affected by air pollutant emissions, such as particulate matter formation, acidification and eutrophication. At the same time, various trade-offs have been observed between the categories that are affected by the emission abatement and those that are instead more linked to energy and resource use. In fact, both scrubbers need consumables for their operation, and these involve an additional impact on the system compared to the base scenario. When considering the balance between emissions avoided and trade-offs generated, the dry scrubber was found to be the best solution.

The results in Spain and in the two farms in Italy showed similar environmental trends in the different scenarios, albeit with slightly variable results in absolute terms. Scrubbers had a greater influence (both positively in mitigation and negatively in trade-offs) in farms in Italy, probably due to their use during phases with longer duration in these farms rather than in the Spanish one, which involved only one phase of the pig lifecycle.

In conclusion, scrubbers are both environmentally interesting technologies and can bring benefits especially in areas where eutrophication and particulate matter formation are locally relevant issues. At the same time, these alone do not solve the problem of the environmental impact of pig farming, which requires various interventions at different levels of the supply chain.

Project videos

In September 2022 and February 2023, two videos of virtual visits in Spanish and Italian farm were posted on the website, social pages and YouTube channel. Both videos are available in Italian, English and Spanish languages.

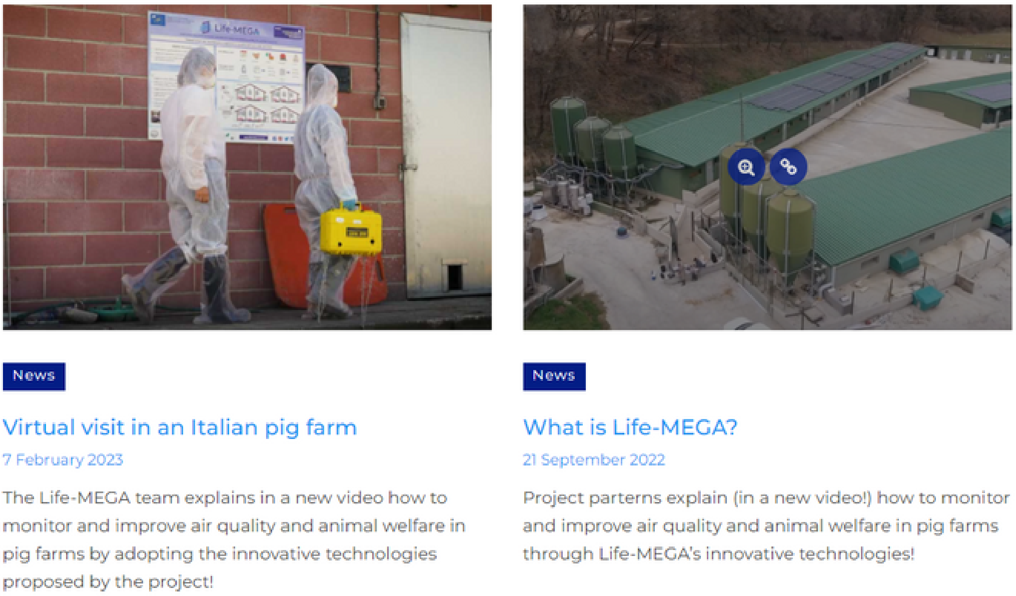

Fig. 7 Virtual visits published on project website

Website and social media

For updates on project activities visit the website: lifemega.unimi.it or follow the project's social media channels:

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