Comparison of abatement solutions for particulate matter and ammonia in pig farming

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Ammonia (NH_3), odours (VOCs, volatile organic compounds), particulate matter (PM), and greenhouse gases (GHG), such as methane (CH_4), are the most abundant pollutants emitted by pig farms. In the European Union, the agricultural sector is responsible for 92% of NH_3 emissions.

NH_3 contributes to indirect emissions of nitrous oxide (N_2O) as well as to acid deposition and eutrophication, causing changes in biodiversity and ecosystem functioning. Moreover, NH_3 plays a significant role in the formation of particulate aerosols in the atmosphere. Secondary aerosols, which have diameters of less than 10 (PM10) and 2.5 microns (PM2.5), are formed in the atmosphere from chemical reactions involving mainly NH_3, nitrogen oxides (NOx), and sulphur dioxide (SO_2).

In the framework of the project LIFE MEGA, two different abatement systems (dry and wet scrubber) were developed and tested to reduce ammonia and particulate matter inside pig barns considering in two different European regions (Lombardy and Catalonia). The dry scrubber is a technology already used in other industrial contexts (e.g., baking), whereas regarding the wet scrubber a prototype using citric acid was specifically developed.

The aim of this study was to approach the sustainability of the pig farming production system from all three points of view for the first time. This has the dual objective of testing the methodological combination of the three sustainability analyses and highlighting any similarities, shared hotspots or even trade-offs of the different layers and having a more complete view of the supply chain impact. A case study was conducted in Northern Italy (Lombardy region), which concentrates a high share of the country's intensive pig farming, by means of primary data collected from closed-cycle pig rearing farms. Two scenarios were compared (Figure 1). The first one analyzes the actual situation of the farm while the alternative one considers the installation of a abatement solution (wet or dry acid scrubber) able to treat ammonia and particulate matter inside the pig facilities.

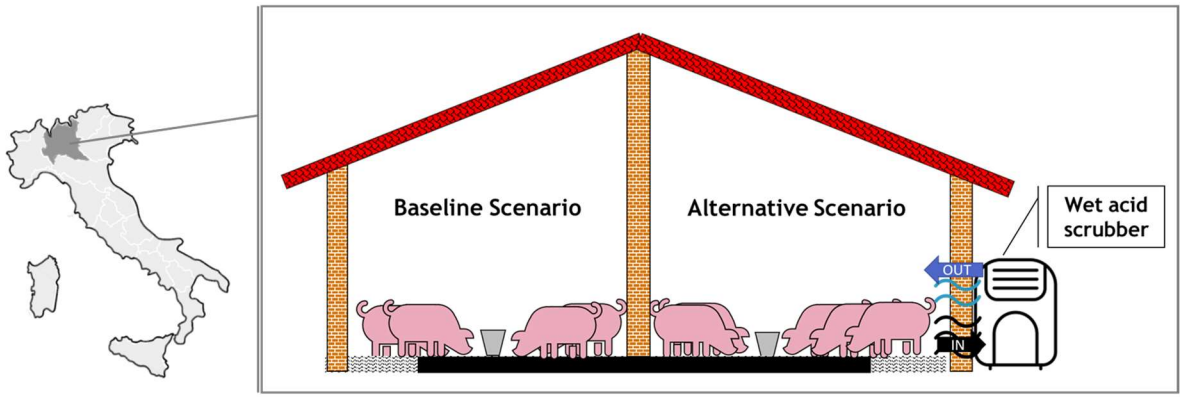

Figure 1 – Schematization of the two scenarios without and with the wet acid scrubber.

Starting from the results, an alternative scenario was explored in which the introduction of an emerging mitigation technique was tested in order to explore its possible influence on the three layers of sustainability. This is represented by an end-of-pipe air treating technology, currently not widespread in the sector in Italy, which concerns air scrubbing to reduce particularly ammonia (NH_3), and even particulate emissions, from the housing phase.

The economic, environmental, and social impacts of an Italian representative pig farm were evaluated using the Life Cycle Thinking (LCA, LCC and SLCA) approach considering two scenarios.

The environmental impact was analyzed with the Life Cycle Assessment in a cradle-to-farm gate approach with 1 kg of live weight (LW) produced, ready to be sold to the slaughterhouse, as functional unit. Primary data concerning farm activities were collected from a questionnaire compiled by the farmer and through personal interviews with the farmer, including the following items: number of animals for each category, housing and ventilation system, slurry management, feed and diets, length and mass of animals in each sub-phase, electricity and fuel consumption. Specifically, the farmer provided all information regarding herd composition, crop

production, animal diets, excreta management, cultivation practice and field operations, fertiliser, fuel, and electricity consumption. Concerning the diet supplied by the farmer, the formulation is mainly based on maize, wheat bran, soybean meal, soybean oil, fish meal, and mineral-amino acid-vitamin additive. However, feed material inclusion rates are confidential and therefore not shown. Secondary data related to estimates of emissions from animals (enteric and manure management), while background data were retrieved from the established Ecoinvent® database. The final inventory was characterized with a midpoint perspective impact assessment.

For the economic side, a cash flow analysis was used taking into consideration all the costs and revenues of the farms involved during a year. Therefore, both the consumables and raw materials used, the cost of labour and services, the depreciation of capital goods, and company production and sales were considered.

The achieved results for the environmental side are in line with other LCA studies focused on pig rearing, with a GWP varying between 3.5 and 4.0 kg CO2 eq/kg LW. Feed consumption is the main environmental hotspot for many impact categories, reaching contributions of 50-70% of the total impact for terrestrial acidification, eutrophication and particulate matter formation, and even greater than 80% for categories related to human and ecosystem toxicity (freshwater). For the GWP the contribution of the feed is lower because also the methane emitted by manure management plays an important role (30-50%).

The feed is also by far the main cost item, varying between 60 and 75% of the total, followed by the costs for work, depreciation capital goods, energy and other factors of production (Figure 2). Given the total production costs which are around 1.1-1.3 €/kg LW, the profit margin is quite low compared to market selling prices. A first consideration that emerges from this result is that farmers cannot easily afford investments to improve environmental and social conditions.

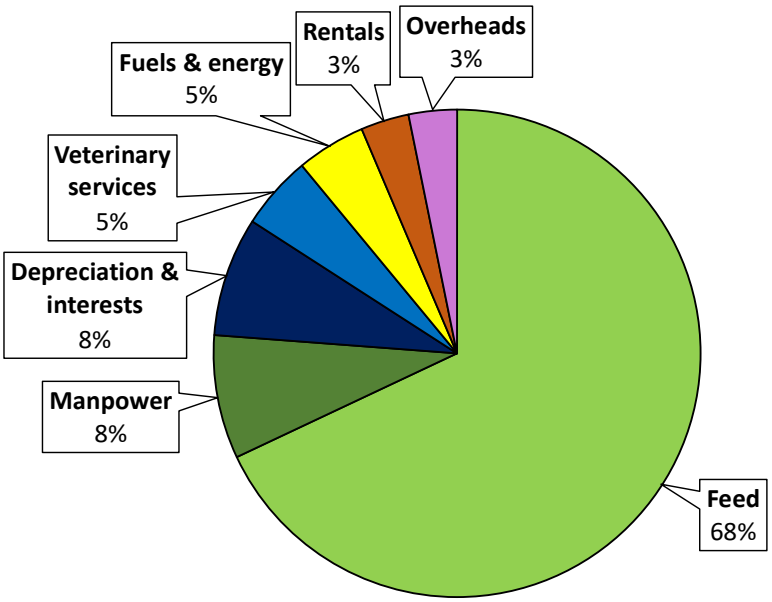

Figure 2 – Breakdown of the production cost

From an environmental point of view, on the other hand, trade-offs between different impact categories emerged. For example, as regards the GWP, the alternative scenario slightly increases its impact (although always < 5%) due to the consumption of raw materials for scrubber operation and despite the slight reduction of indirect N2O emissions (thanks to the avoidance of part of the volatilization and soil re-deposition and denitrification of NH3). However, impact categories linked to NH3 emissions such as acidification and PM formation potential noticeably reduce their impact in the order of 10%. The way of modelling the co-production of ammonium solution effluent has an influence on the results. If we consider that this could replace synthetic nitrogen fertilizer otherwise bought externally by the farms, this generates a significant environmental credit. From the economic side, the installation of the air scrubber was estimated with a total cost varying between 3.4 and 17.2 €/pig place/year depending on the operation and removal efficiency. The results from the social analysis scored better for the alternative scenario, which is linked to improved values especially on the animal welfare indicators.