Deliverables D43-44 action C2

Report - Quantification of the implementation costs of the sustainability actions referring to the product unit (kg of milk)

Report - Quantification of the costs of the services provided to the territory as reduction of impacts (GHG gas and air pollution)

Definition

Slurry: livestock faces. Cattle slurry has an average total solid around 9%.

Manure: mix of livestock faces and straw, average total solids around 18-20%

Shredded manure: Manure subjected to cleaning (removal of stone and metals) and shredding to shorten straw length, in order to be suitable for the biogas plant.

Slurry derived fractions (SDF): fractions obtained from slurry and manure thanks to a specific treatment. Slurry-manure derived fractions are: **Shredded manure**, **Separated Solid fraction of slurry, Cavitated slurry -manure mix.**

Separated solid fraction of slurry: fraction of slurry separated from liquid to be suitable for transport and delivery to biogas plants. An average total solid of this fraction is 16-18%.

Cavitated slurry-manure mix: mix of slurry and manure, which undergo treatment in the prototype device to be realized in the project. The objective of the treatment is to make the materials more suitable for biogas plants, i.e. to produce a material with high total solids content, high homogeneity, high digestibility, and pumpability.

Introduction

The LIFE DOP project aims to decrease the environmental footprint of the dairy sector, which is an important source of income, culture and social cohesion for the territory. The production of the 2 PDOs (Parmigiano Reggiano and Grana Padano), has a long history of quality and excellence; still, it is a sector that must innovate for what concerns to environmental sustainability: i.e. the reduction of GHG and ammonia emissions (Emission Ceilings Directive 2016/2284/EU). It is to remark that at present, ammonia emissions and the linked production of particulate matter, is becoming a relavant health issue, as the Lombardy area is a closed basin in which air pollution stagnates for a long time and produce hazard for citizens.

The pillars of LIFE DOP ideas to improve environmental sustainability are:

1) to use slurry-manure derived fractions to produce renewable energy, avoid methane emissions and produce renewable energy. The model implemented in the LIFE DOP project provides that: i) slurry and slurry-manure derived fractions (shredded manure, separated solid fraction of slurry and cavitated slurry-manure mix) are sent to anaerobic digestion plants , ii) the biogas plants replace the amount of energy crop they were using with the slurry-manure derived fractions.

2) to improve the use of "recovered nutrients". Digestate is used in total replacement of synthetic fertilizers, lowering the impact of production and greatly enhancing NUE (Nitrogen Use Efficiency). Maize is one of the primary feeds for milk production. Synthetic nitrogen is extensively used to cultivate corn (i.e. urea is supplied at the raising of maize), while the nutrients of the slurry are distributed mainly in autumn, causing very low NUE. This practice is partly due to the problem of very clayey soil in the area, that prevents the proper distribution of slurry and digestate at the raising of maize, and due to the management practices in places in the farms, where the distribution of slurry is performed when there is more time and no other operations are more urgent.

The proposal of the LIFE DOP Project is to eliminate the synthetic nitrogen and to distribute digestate by injection or by fertigation at the raising of maize (to reduce ammonia emissions, leaching and thus increasing the NUE of digestate).

The use of the digestate instead of the slurry ensures better NUE, since the ammonia nitrogen is in the liquid digestate more than 70% of the total nitrogen, and is therefore readily absorbed by maize at the time of rising (stage 3-6 leaf of the growth cycle). The distribution by injection or fertigation at the maize rising stage makes it possible: i) to avoid the use of synthetic nitrogen into the system, ii) to reduce the emissions of ammonia into the atmosphere, ii) to supply nitrogen to the culture at the time of highest demand, reducing leaks into the soil and water system.

3) Export **of excess nutrients in non-livestock areas, improvement of the soil quality in non-livestock areas and benefits to the soil in non-livestock areas**: The amount of N and P in the digestate coming from slurry derived fractions (**see pillar 1)** increased of 2-3 times respect to baseline digestate (biogas plants using only corn). The higher content of nutrients makes the solid fraction of digestate more valuable for the export in non-livestock areas (the high fertilizer value justifies transport). Trials during the project demonstrated the improved production of thesis fertilized by solid digestate compared with synthetic nitrogen in non-livestock areas.

4) Improve stables efficiency and sustainability: the ARA Lombardia (Associazione Regionale Allevatori) technicians have minutely monitored the production data and the production inputs used in 94 stables and have proposed to the companies, based on the collected data, four areas of improvement to be pursued by changes in company management, to increase the dairy efficiency and feed self-sufficiency. 10+13 pilot companies werw followed step by step in the implementation of management improvement plans.

5) Identification of possible structural and management improvements in cheese dairies

During the LIFE DOP project, we gathered project data and data from on the ground experience, to outline the costs of the good practices able to reduce emissions and increase sustainability. The deliverable put in line all the costs of each operation needed to decrease the impacts.

The data were gathered from field experiences in the demo-fields and simulations were run to verify the costs in companies located in the districts, namely in the municipalities of Pegognaga, Gonzaga, Monteggiana, Borgo Virgilio, San Benedetto Po.

Although the costs have been calculated and verified for the specific companies in the mentioned municipalities of the PDOs, the practices are perfectly applicable within the same range of costs in all conditions of intensive lowland farming.

Report 1- Quantification of the implementation costs of the sustainability actions referring to the product unit (kg of milk)

Environmental practices for sustainability and costs

The good practices tested during the project and the related costs are described in the next paragraphs. Some solutions were not implemented within the project as they were in place in the project premises previous of the project start (digestate covered storage). These solutions are anyhow reported in this document to provide a complete overview of "what to do" and "how much it costs" for improving the dairy sector sustainability.

Some of the practices, such as Anaerobic Digestion (AD) of slurry and Slurry Derived Fractions (SDF) also generates revenues from the production of renewable energy. The renewable energy is now rewarded according to a feed-in tariff incentive that will end in 2025. From that date, electricity will probably be paid according to market rates.

Costs are highlighted in red, and **revenues are highlighted in green,** to simplify the reading of the tables.

Practices for reducing methane and GHG emissions

First step: adding Anaerobic Digestion (AD) in the management practices of dairy farms to treat slurry. The AD is a useful process for the treatment of slurries and by-products as it reduces methane emissions due to slurry storage. The limit of this approach is that small farms cannot afford an AD plant for their own and that some materials (such as solid manure, are not easily managed in the biogas plants). The LIFE DOP approach was set to set up a district model to collect slurries and Slurry Derived Fraction (SDF), to pre-treat these fractions, to transport and deliver them to the biogas plants. SDFs need treatment such as separation or cavitation, whose average cost is around 4 euro/ton. At present, the electricity produced from anaerobic digestion is rewarded 0.28 Euros/kwh, and this is the revenue for AD treatment, that largely compensate costs. In table 2 are reported the operations and costs referred to one unit (ton) of material (slurry or SDF).

Below are reported the main parameters used in the calculations

Table 1: parameters used for calculation

Energy revenue feed-in tariff	€/kwh	0.28
Energy revenue in the free market	€/kwh	0.16
CO_2 eq saving by renewable energy	g CO2 eq/kWh	243*

*The reference system is the electric energy generation from fossil fuel in Italy 493.8 g CO2eq/kWhe] (ISPRA, 2020). The biogas from slurry and SDF costs 250 CO2eq/kWhe (precautionary estimate)

Calculation of costs referred to the unit of slurry or RDF

Table 2: operations and costs to reduce methane emissions from slurry and SDF (calculation referred to the ton of slurry or SDF)

Operations	Unit	Implementation cost
Transport of slurry or SDF (within 10 km and digestate back)	€/ton	**4**
Treatment (only for SDF, separation or cavitation, avereage capex and opex)	€/ton	**2**

Anaerobic digestion costs (capex+opex)	€/ton	**4**
Covering digestate storage (capex, 10 years of depreciation)	€/ton	**1.2**
New storage tanks to double storage time (330 days) and have efficient precision distribution (capex)	€/ton	**2.5**

In table 3 are reported the revenue from AD (energy sold to the national grid) at present and after supporting scheme for electricity end

Table 3: revenue for AD of from slurry and SDF

Operations	Unit	Reveneu
Revenue at present for electricity from slurry AD	€/ton slurry	**12**
Revenue for electricity from slurry AD after supporting scheme for electricity ends	€/ton slurry	**7**
Revenue at present for electricity from SDF AD	€/ton SDF	**25**
Revenue for electricity from SDF AD after supporting scheme for electricity ends	€/ton SDF	**13**

Reducing ammonia emissions

The control of ammonia emission is becoming an increasingly concerning issue as it was demonstrated that it is a precursor of particulate matter (PM) linked to pulmonary diseases (Raaschou-Nielsen, 2013). Recent data from the Lombardy Region Environmental Protection Agency (ARPAL, 2015) indicated that about 96% of ammonia polluting the air in Lombardy is from agricultural activity, mainly livestock activities. These data agree with international literature (Clarisse et al., 2009). Ammonia is responsible for water eutrophication, acid deposition, and secondary particulate formation (Renard et al., 2004). The presence of particulates has been recently reported to be a direct cause of lung cancer (Raaschou-Nielsen et al., 2013) and EU legislation address the issue calling into question the agricultural sector to make its part and adopt specific measures to respect ceilings. The National Emission Ceilings Directive 2016/2284/EU has set an obligation for all European Union countries to reduce the NH_3 emissions by 6%, relative to 2005, by 2020

The practices tested in the context of LIFE DOP to reduce emissions and relative costs are listed in table 4.

While standard practices for slurry and digestate distribution is splash-plate equipment, in LIFE DOP two different practices were tested in the context of PDOs production: injection of digestate and drip-fertirrigation. They demonstrated to reduce ammonia emission by 40% (at least) respect to splash-plate distribution.

In table 4 are recapped opex and capex of each operation and comparison with baseline.

Table 4: operations and costs to save ammonia emissions in the dairy sector

Operations	Unit	Implementation	Baseline
Covering digestate storage (capex, 10 years of depreciation) already mentioned in table 2	€/ton	**1.2**	0
Digestate injection Baseline is the simple distribution of digestate by splash-plate distribution	€/m³	**4**	1.5
Drip irrigation operative cost (including digestate treatment by micro-filtration). Baseline includes the simple distribution of digestate by splash-plate distribution (it does not include the cost of irrigation that has anyhow to be provided)	€/m³	**3.0**	1.5
Drip irrigation capital cost (equipment for drip irrigation and digestate treatment by microfiltration).	€/m³	0.75	0
Cost of digestate management (injection)	€/Kg milk	**0.0046**	

From data reported in table 2 3 and 4 is possible to calculate the balance in expenditure and costs related to the management of slurry in storage and fields to decrease GHG and ammonia emissions. For simplicity the costs are referred to the unit of produced milk (table 5), and finally are expressed as percentage of the gross sales of the milk for different production chains (Grana Padano PDO milk, Parmigiano Reggiano PDO milk, simple milk for consumption) (table 6)

Table 5: costs related to the management of slurry in storage and fields to decrease GHG and ammonia emissions. Referred to the unit of produced milk

Operations	Unit	Implementation
Cost of slurry management (AD and related operation) for each kg of milk (without incentive)	€/Kg milk	**0.0092**
Cost of digestate management (injection)	€/Kg milk	**0.0046**
Total cost for environment sound measure (AD and injection)	€/m³	0.014

Table 6: costs related to the management of slurry in storage and fields to decrease GHG and ammonia emissions. Referred as percentage of the gross sales of produced milk

Milk revenue for PR	€/Kg milk	0.5
Milk revenue for GP	€/Kg milk	0.42
Milk revenue for common milk	€/Kg milk	0.33

Cost for environmental sound practices in PR	% of income at present	2.8%
Milk revenue for GP	% of income at present	3.3%
Milk revenue for common milk	% of income at present	4.2%

Increasing dairy efficiency in the stables

According to data coming from B5 action in LIFE DOP project (audit data depicting the state of the art of stables in the two PDO and data collected in the implementation of "customized improvement plans" implemented in 23 stables), there is a clear correlation between Dairy Efficiency (DE) and the reduction of GHG emissions and global improved environmental outcomes.

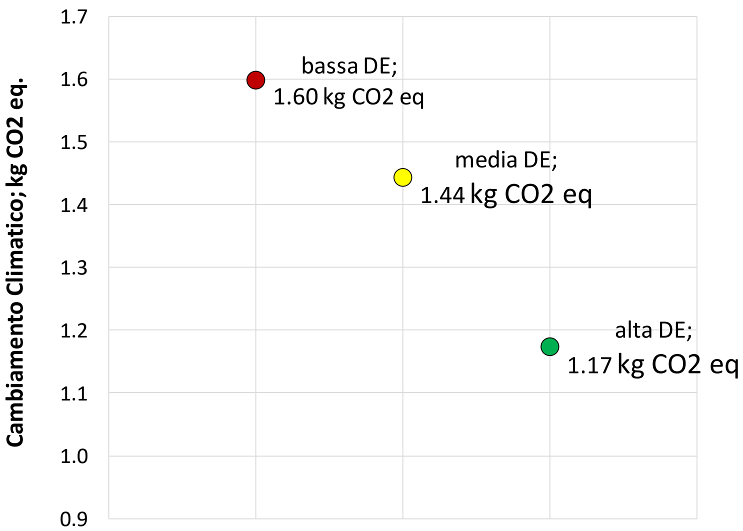

Figure 1: correlation between DE (x-axis) and CO_2 emissions of milk (y-axis). Higher DE leads to lower CO_2 emission for each kg of milk.

The increase of DE in stables is a complex mix of different interventions that includes areas such as feeding (quality and quantity), fertility, well-being, hygiene, etc. Some measures are management measures (protocols to perform better management of routine operations), while some include capital investments in buildings (new stables, with specific dedicated areas for rest and feeding) and equipment's (milking robot, pedometers, sensors, ventilators and climate conditioning equipment's). Simple improvement plans such as better management of the hygiene of the bedding of cows (reduction of mastitis) and rejuvenation of the herd, if amortized in 5 years, cost about 10.000 €//year (capex and opex). That would be 5 Euros for each ton of milk or 0.005 euro/kg of milk. But these improvements lead in one year to increase the production and quality of milk to an extent, that the expenses are more than compensated in only one year. Each situation and each stable is a unique environment in Mantua PDOs production, so the project is not able to provide standardized calculations and standardized costs or practices. Anyhow the improvement plans demonstrated that also management and low investment-cost practices can lead in less than one year to decrease CO_2 emissions from 5-to 15% only considering the management of the stables.

Conclusion report 1. Producers and consumers perspective

Finally we can say that the implementation of environmentally sound measure for the production of milk, is , for high added value chains and PDO cheese, between 4-and 4% maximum of the gross sales of produced milk. This means that a negligible increase in price at consumer level (5%) could completely compensate the costs of these practices and investments.

The incidence of costs is different in different production chains, and common milk is the less robust production chain for what concern value and resilience to market fluctuation. So PDO productions are the more likely production to be able to start the implementation of environmental measures and to valorise their positioning on the market by commercial claims related to sustainability

Report 2 - Quantification of the costs of the services provided to the territory as reduction of impacts (GHG gas and air pollution)

Based on the data and calculation performed to outline costs for reducing GHG and ammonia emissions referred to the unit of milk, the same calculation of costs are now referred to the unit of saved CO_2 equivalent and avoided ammonia emissions in air. The calculation is intended to outline the total budged the system (producers, consumers, citizens, tax payers) have to put in place to reduce emissions in this sector. In the calculation is considered and subtracted the service of producing electricity, according to a market value of 0,16 euro/kwh.

	Unit	Implementation
Costs for CO_2 saving from slurry	€/ton CO_2 eq.	**141**
Costs for CO_2 saving from slurry from SDF	€/ton CO_2 eq.	**4**

The lower costs of CO_2 saving from SDF is due to the fact that the SDF fractions such as manure or Shredded manure, Separated Solid fraction of slurry allow a specific saving of methane higher than slurry, allow a higher production of energy and the related costs (transport…etc..) are less relevant. Still the total of al the volume of slurry in AD allows the avoidance of all the GHG emissions, respect to the treatment of the fractions.

Operations	Unit	Implementation cost
Marginal cost to avoid ammonia emission by coverage of storage tank and proper management of digestate in fields (injection)	€/kgNH3	1600
Marginal cost to avoid ammonia emission by coverage of storage tank and proper management of digestate in fields (fertigation)	€/kgNH3	1400

The lower costs of the fertigation is contextual, as in the reference territory the practices of irrigation is performed by low pressure pumping (which is the baseline cost) and not by sliding (which is very cheap). The distribution of digestate by fertigation should take into account the baseline costs of digestate distribution and irrigation.

Conclusion Report 2. Citizen and community perspective

Cost for the reduction of methane emissions in dairy production ($CO_{2\ eq}$)

The cost for the reduction of the emission of 1ton CO_2 eq in the dairy sector is equal to **141** €/ton CO_2 eq. and the cost for the reduction of the emission of 1ton ammonia in the dairy sector is equal to **1400-1600** €/ton NH_3.

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