FARMING FOR FUTURE

10 ACTIONS TO FARM THE FUTURE.

CIB
CONSORZIO ITALIANO BIOGAS

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"All life depends upon the soil.
There can be no life without soil and no soil
without life; they evolved together."
Charles E. Kellogg

FARMING FOR FUTURE

10 actions to farm the future.

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PRESENTATION

Italy has for decades been the country with the largest number of typical food products in the world and has the biggest food and wine biodiversity; hence, faced with the opportunity to receive an economic incentive to promote electricity generation from biogas, we would not think of doing it stopping feed production to make Parmigiano-Reggiano and other PDOs. Conversely, we are relying on anaerobic digestion to radically change the way we produce such foods and feed. Indeed, by opting for on-farm anaerobic digestion everything can change in farming practices: chemical fertilization gives way to organic fertilization with digestate, crop rotations and double crops are intensified, precision and conservation farming techniques and an efficient use of water become more common, livestock effluents and agro-industrial by-products are no longer considered as waste, rather resources. In other words, we are encouraging a new integrated solution for producing food, feed and energy. This is what Biogasdoneright® is all about, a journey to transform agricultural and animal husbandry practices from an agro-ecological standpoint. After a few years of practice, we can totally confirm that "it works and serves environmental and economic purposes."

Meanwhile, the climate crisis is exacerbating, CO_2 emissions keep rising, despite repeated and clear warnings from international experts all over the world. The European Commission has approved a European Green Deal and outlined a number of strategies that aim to make Europe become the first continent climate-neutral by 2050: therefore, all sectors must act to reduce its emissions rapidly, including agriculture in a net zero perspective.

As a result, Italian farming and livestock are also facing a major challenge: on the one hand they must contribute to mitigate climate change by reducing their emissions and impact on natural resources, but at the same time their role and value in protecting such resources must be acknowledged, starting with soil, not necessarily reducing production, but rather adopting agroecological production systems, to produce more using fewer resources more efficiently.

This is the framework of the proposal put forward by farmers, industries and technicians affiliated to the Consorzio Italiano Biogas:

FARMING FOR FUTURE – TEN ACTIONS TO FARM THE FUTURE

Anyone who wants to take up this pressing challenge and give their contribution in terms of plans and actions is welcome to accept our proposal. We are confident that a joint effort by the business world, associations and institutions will help our country find the necessary human and financial resources to redesign agricultural production towards full sustainability, while integrating its economic, environmental and social value.

Piero Gattoni
Lodi, December 2020

1. CLIMATE, ENERGY, AGRICULTURE: BACKGROUND

The IPCC Special Report of October 2018 has once again stressed the importance of limiting the global temperature increase to approx. 1.5 °C to avoid reaching "climate tipping points"[1]. To achieve this goal and to cope with possible overshoots and delays, it will be necessary to adopt a rapid action strategy involving the energy and industrial sectors. In addition, emission reduction from the use of fossil energy in all industries must be combined with initiatives aimed at removing carbon from the atmosphere, for example through the so-called 'carbon-negative' systems.

The most recent IPCC Special Report on Climate Change and Land[2] reaffirmed the importance of soil and farming methods as drivers of climate change mitigation. The report emphasises the need to act on agricultural production by adopting all the necessary measures to sequester carbon and reduce emissions, and considers bioenergy as one of the solutions to be deployed, provided that this is done in an appropriate and adjusted manner depending on the contexts of reference.

In short, it has been acknowledged that thanks to the photosynthesis triggered by farming, the agroforestry sector is the only one capable of guaranteeing a significant sequestration level in line with the planet's carbon cycle[3].
Already in 2017, distinguished academics had identified farming, and the biosphere in general, as one of the "natural climate solutions" for removing atmospheric CO_2, having multiple benefits and few, or no risks[4].

As Nobel Prize winner Prof. Rattan Lal has repeatedly pointed out that, in fact, in order to feed the ever-growing population and at the same time fight climate change, it would be necessary to adopt "farming methods that produce more from fewer resources: less soil, less water, fewer nutrients." According to Prof. Rattan Lal, the adoption of agro-ecological practices centred on soil fertility conservation and regeneration and the development of photosynthesis in cultivated and non-cultivated land could potentially reduce the atmospheric concentration of CO_2 by around 156 ppm in the 21st century[5].

With regard to the role that the agri-food sector can and must play in terms of sustainability and the fight against climate change within the European Green Deal, the Commission has indicated a number of goals in the Farm to Fork and Biodiversity strategies, one can easily agree on some of them (reduction of chemical fertilisers, pesticides, antibiotics) while others deserve deeper analysis, as they risk undermining the production potential of the European farming sector, and the Italian in particular. The concept of extensive production from cultivated land, the 'prejudice' against meat consumption and livestock farming - along with other issues, like the reintroduction of the ''set aside'' system to safeguard biodiversity – open up a development scenario that cannot be fully embraced by an innovative and high-quality farming sector such as the Italian.

Italian agriculture, a world leader in high-quality foods, intends to produce more while polluting less by integrating anaerobic digestion in farms. Actually, this vision for the future of agriculture and livestock has a lot in common with the goals outlined in the European strategy to improve the overall impact of farming (fewer chemical fertilisers and fewer pesticides). There are two key points to highlight, though: the conservation of the Italian livestock heritage and the intensification of production (more photosynthesis with less input per product unit), which is closely linked to the fertility of cultivated land (thanks to a positive carbon balance).

[1] IPCC Report 1.5°C (https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments)
[2] "Climate Change and Land" IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse gas fluxes in Terrestrial Ecosystems. August 2019 (https://www.ipcc.ch/report/srccl/)
[3] http://www.fao.org/global-soil-partnership/en/
[4] Griscomb B.W. and others (2017) "Natural Climate Solutions", PNAS; 2017 (http://www.pnas.org/content/pnas)
[5] Rattan Lal, Nobel Conference 2018 - Living Soil: A Universe Underfoot. 2-3 Ottobre 2018

2. EMISSIONS FROM ITALIAN AGRICULTURE TODAY

2.1 GHG EMISSIONS FROM AGRICULTURE

In 2018, total GHG emissions from farming (Figure 1) amount to 38.4Mt CO_2 eq.
Of these, 8.3 Mt of CO_2eq. were due to energy consumption and 30.2 Mt to production and livestock. These stages require particular attention (Table 1, Figure 2).

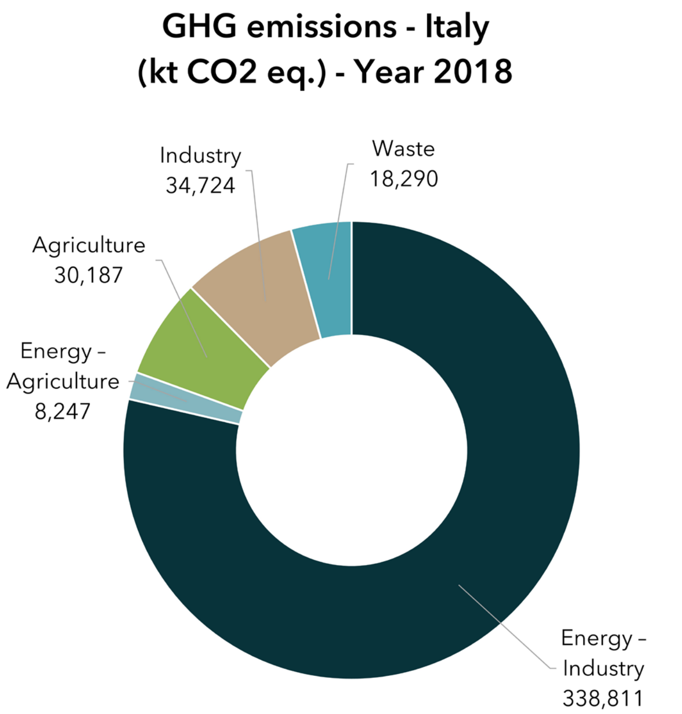


FIGURE 1 – Total Italian GHG emissions - Year 2018 (Source: ISPRA, National Inventory Report - NIR 2020).

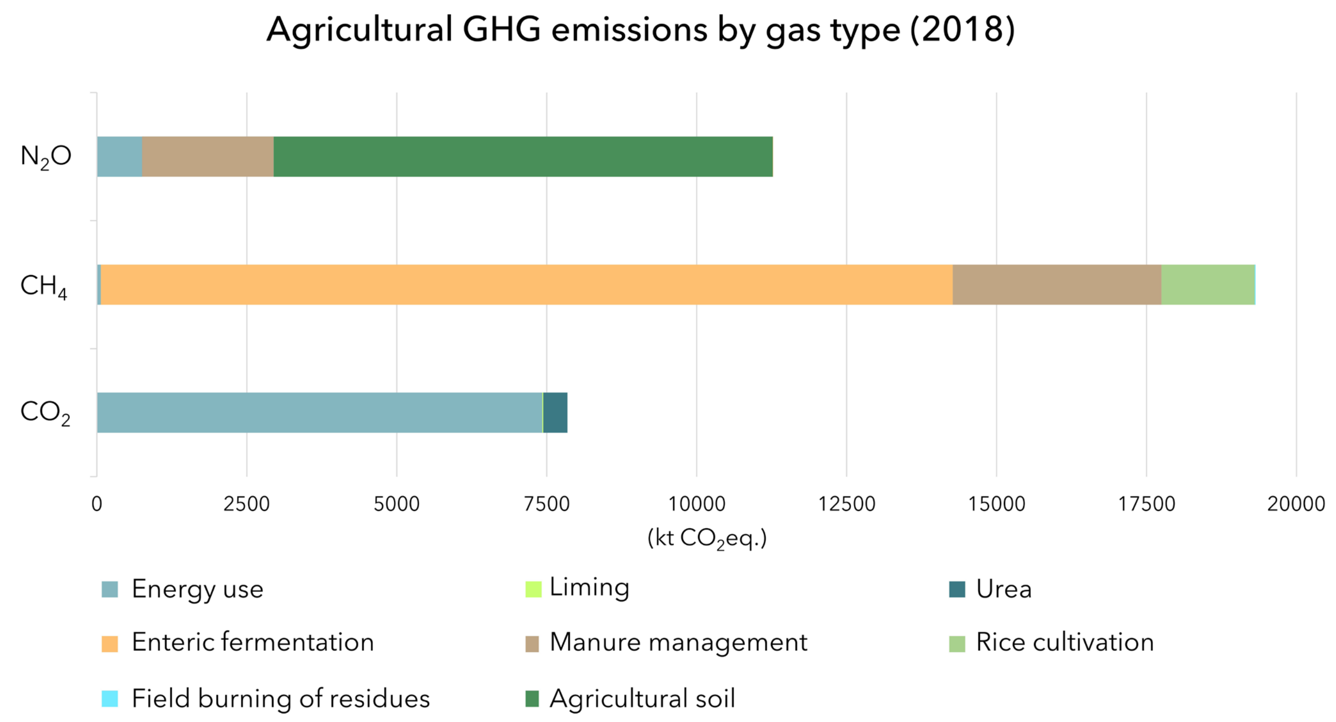
As is well known, agriculture and animal husbandry mainly generate methane (CH_4) and nitrous oxide (N_2O) emissions, as well as ammonia (NH_3), rather than CO_2 emissions; in 2018, agriculture was the main source of CH_4 and N_2O, accounting for 45% and 58% of the national total respectively, while CO_2 emissions totalled 0.2% of the national amount.

Methane emissions come primarily from enteric fermentation (73.8% of CH_4 emissions) and livestock effluent management (18.1% of CH_4 emissions), followed by rice growing and crop residue burning.

		kt CO_2 eq.	kt CO_2 eq.	% total gas	% total
CO_2	Energy use	8,247	8,667	22.6%	21%
	Liming	15			0%
	Urea	405			1%
CH_4	Enteric fermentation	14,202	19,251	50.1%	37%
	Manure management	3,480			9%
	Rice cultivation	1,553			4%
	Field burning of residues	15			0%
N_2O	Manure management	2,190	10,516	27.4%	6%
	Agricultural soils	8,322			22%
	Field burning of residues	4			0%
TOTAL		38,434		100%	100%

TABLE 1 – Details of agriculture-related emissions - Year 2018 (Source: ISPRA - NIR 2020).

Finally, nitrous oxide emissions are produced by nitrogen added as part of agronomic soil management (79 % of N_2O emissions) and by the handling of livestock effluents (20.8 % of N_2O emissions), as well as crop residue burning.



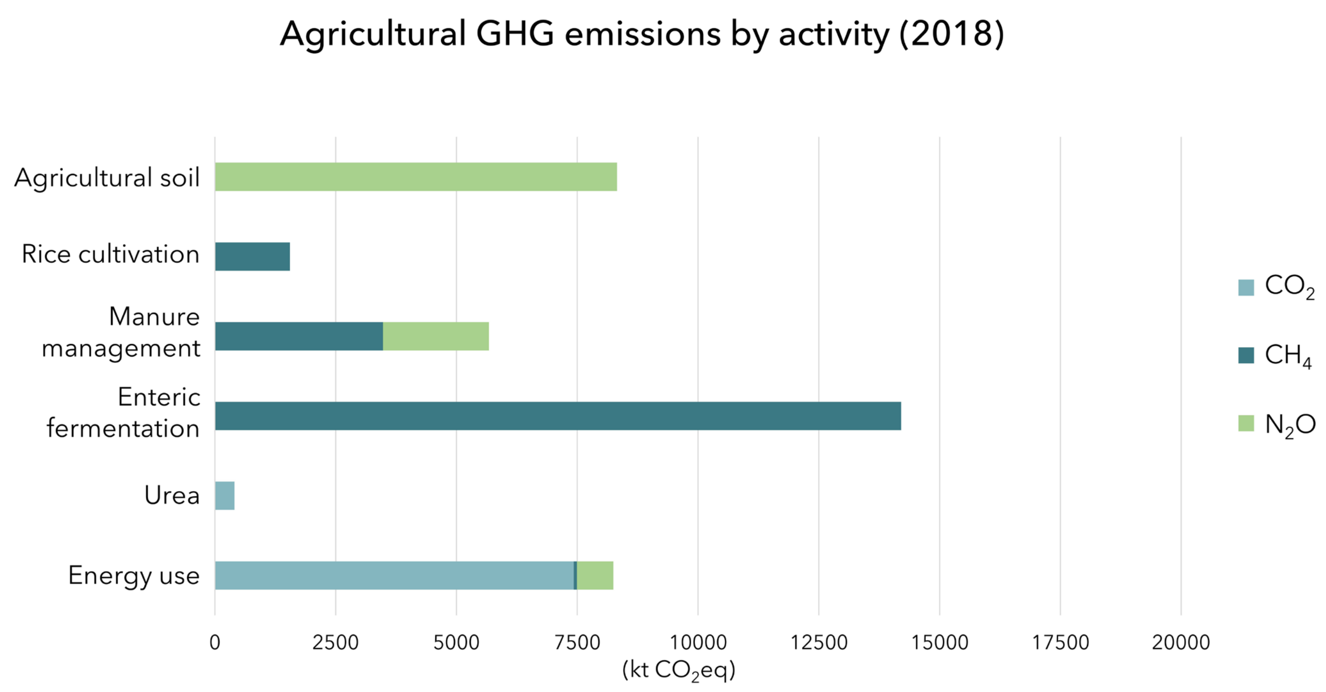


FIGURE 2 – Breakdown of GHG emissions from agriculture by type of GHG and by type of activity (Source: ISPRA, NIR 2020).

2.2 AMMONIA EMISSIONS FROM AGRICULTURE

Ammonia (NH_3) is an air pollutant, mainly produced from farming, that can have significant effects both on human health and on the environment.

In 2018, national ammonia emissions from farming amounted to 345 kt, 94% of the total (Ispra, IIR 2020), 80% of which from livestock. These emissions trigger soil and water acidification phenomena and are jointly responsible for the formation of fine and ultrafine atmospheric particulate matter (PM_{10} and $PM_{2.5}$).
In 2018, the main emission source was livestock management (emissions from animal housing and manure storage), representing 59% of total NH_3 emissions from farming (Figure 3). Other important emission sources in this sector are distribution of manure (20%) and synthetic nitrogen fertiliser application on soil (15%). Other minor sources are the use of other organic fertilisers, grazing, sewage sludge distribution and nitrogen fixed to the soil through the nitrogen-fixing process triggered by legume roots.

Based on the above data and given the contribution of farming in terms of GHG and ammonia emissions, it seems clear that **livestock farming in all stages of the production cycle (from animal housing to the management of livestock effluents and their agronomic use) carries the greatest weight. Any proposal or action aimed at reducing its emission impact, will have a positive effect both on the reduction of CO_2 eq. (CH_4 and N_2O above all) and the ammonia emissions.**

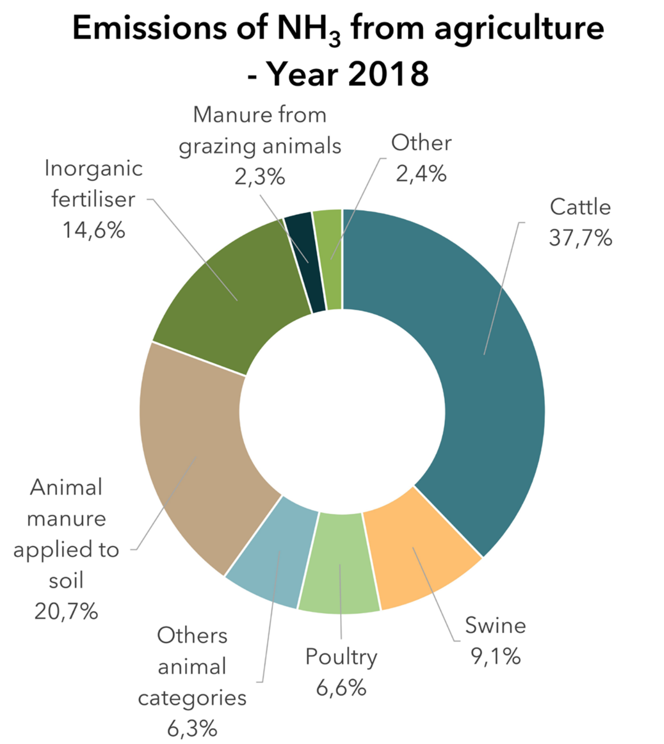


FIGURE 3 - Contribution of different sources to ammonia emissions from the agricultural sector (Source: elaboration on Ispra data - Informative Inventory Report - IIR 2020).

3. AGRICULTURE AS ACTIVE PLAYER IN THE FIGHT AGAINST CLIMATE CHANGE

3.1 GUIDELINES FOR THE AGRO-ECOLOGICAL CONVERSION OF AGRICULTURAL ACTIVITIES

Agriculture can play a key role in fighting climate change: indeed, it stands in a quite unique position to capture CO_2 from the atmosphere through photosynthesis, thereby transforming it into a wide range of foods, feed, materials and energy (electricity, heat, fuels).
By enhancing and optimising this ability to capture and sequester atmospheric CO_2, farming can not only sharply reduce its greenhouse gas emissions from food production, but also capture and sequester additional CO_2 from the atmosphere, to the point of becoming carbon neutral, and later "net negative".

In order for agriculture to really move in the right direction to become part of the solution in the fight against climate change, it must reorganise its production along three specific guidelines:

1. Placing soil at the centre of every strategy, rearranging and improving agronomic management to increase production (photosynthesis), as well as fertility by restoring organic substance supply and biodiversity;

2. Increasing production efficiency to suit the needs of the many supply chains that make up the agricultural and agri-food sector in Italy (input reduction per product unit, rather than absolute values);

3. Promoting the production and use of sustainable renewable energy and bioeconomy in general.

These guidelines shall be fully implemented once biogas production is integrated in farms in line with the principles of Biogasdoneright®; on-farm anaerobic digestion, regardless of production choices, promotes a new agro-ecological approach for farming in general.

3.2 ON-FARM BIOGAS PLANTS

The perfect integration between renewable bioenergy and food production is possible through anaerobic digestion. In fact, anaerobic digestion differs from other bioenergy sources for two reasons: the intrinsic peculiarities of the process and the agronomic practices it makes possible, known as "Biogasdoneright®" [6]. More specifically:

- anaerobic digestion is a natural biological process, optimised on-farm, whereby the organic carbon released by incoming biomass follows different paths (Figure 4): it serves as CH_4 and CO_2 in biogas and residual organic carbon in digestate. The latter is either stored permanently in the soil or released by microbial respiration;
- Through anaerobic digestion, a partial mineralisation of the organic matter and, therefore, of the organic carbon takes place. As a result, all the nutrients contained in the biomasses are retained in digestate, but in a more assimilable form for crops. As a result, organic fertilisation can replace chemical fertilisation, even in farms with no livestock;
- Thanks to co-digestion it is possible to use livestock

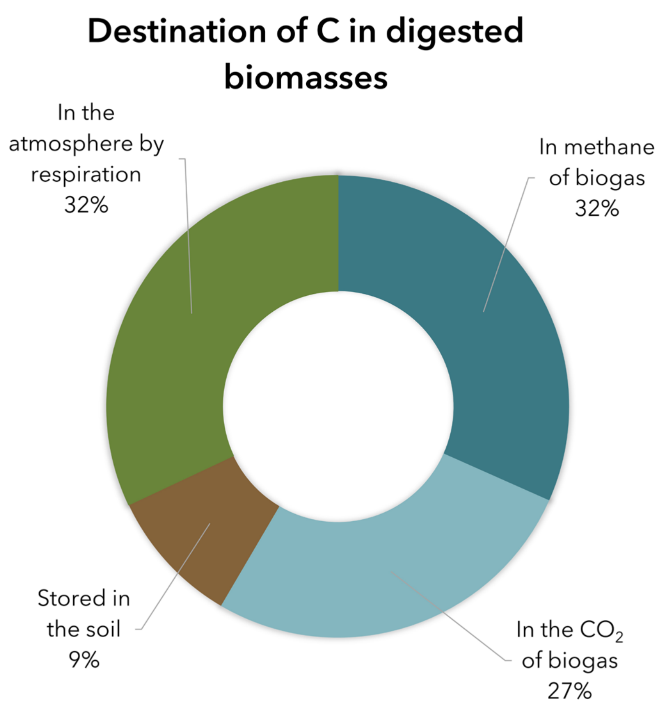


FIGURE 4 – Distribution of carbon destination in biomass sent to anaerobic digestion (average values).

[6] CIB Consorzio Italiano Biogas "BIOGASDONERIGHT® - Anaerobic digestion and soil carbon sequestration. A sustainable, low cost, reliable and win-win BECCS solution" (http://www.consorziobiogas.it/Content/public/attachments/527-Biogasdoneright%20No%20VEC%20-%20LowRes.pdf).

manure, agricultural residues and agro-industrial by-products having varied characteristics in terms of quality and exploit resources at best, thereby reducing any related harmful effects on the environment;

- To obtain the biomass for the digester it is therefore necessary to abandon monocultures and opt for crop rotation, including cover crops, catch crops and nitrogen-fixing crops. This way, green manure will be unnecessary since organic fertilization will use digestate;
- The increased intensification of land use resulting from the spread of cover crops develops in farmers a natural disposition towards innovation and in particular to the use of conservative and precision farming techniques, thus creating the conditions for a rapid introduction of technologies for Agriculture 4.0.

In particular, the pillars for the future agro-ecological conversion of farming through anaerobic digestion are essentially three (Figure 5):

- the use of livestock effluents;
- organic fertilisation with digestate;
- the introduction of double crops (ecological intensification of production, in other words, photosynthesis).

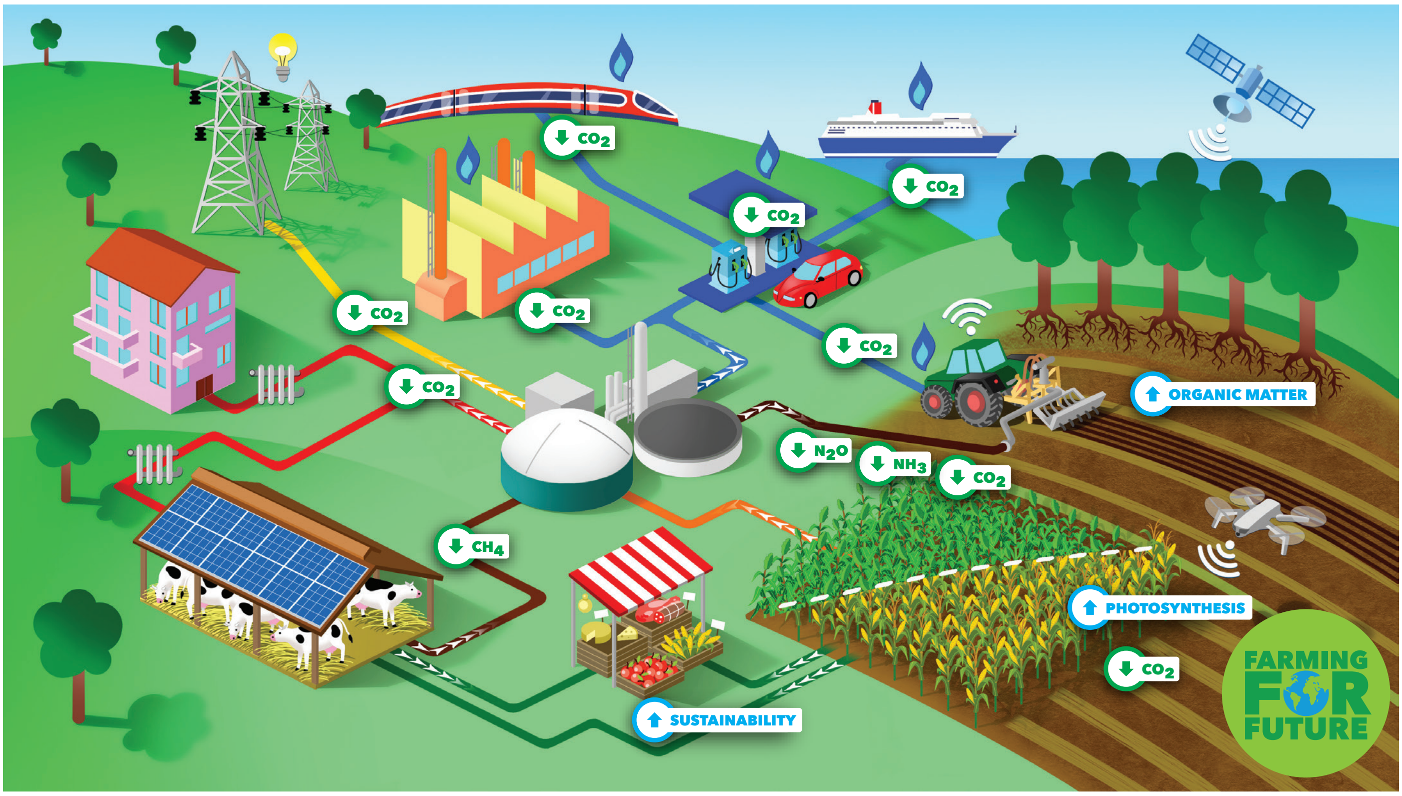


FIGURE 5 – Agriculture is able to produce food and energy thanks to the anaerobic digestion plant: valorization of livestock effluents, diffusion of cover crops, organic fertilization with digestate instead of chemical fertilizers and production of biomethane (renewable gas that can be used for various purposes).

3.3 THE USE OF EFFLUENTS IN ANAEROBIC DIGESTION FOR EMISSION REDUCTION

The anaerobic digestion of livestock effluents, whether shovelable or pumpable, is the most effective technology to limit - or even eliminate - GHG emissions from livestock farming.

In fact, the organic matter of effluents, i.e. vegetable products partially digested in the stomachs of mono- and polygastrics, is characterised by a potentially very high microbial activity that results in the production of considerable quantities of methane.

Using effluents for anaerobic digestion allows to:

1. Reduce direct emissions of methane (CH_4) and ammonia (NH_3) given a shorter interval between excretion and digestion;

2. Reduce emissions of ammonia (NH_3) and nitrous oxide (N_2O), due to the airtight design of the digester and the lack of oxygen therein;

3. Degrade around 50-60% of the organic matter and increase the proportion of mineral nitrogen (in ammoniacal form), which is more easily assimilated by crops;

4. Produce an easily usable gas to supplement fossil natural gas without limits, thus replacing other fossil energy with a greater environmental impact;

5. Produce an organic fertiliser with high agronomic efficiency and a high humification index.

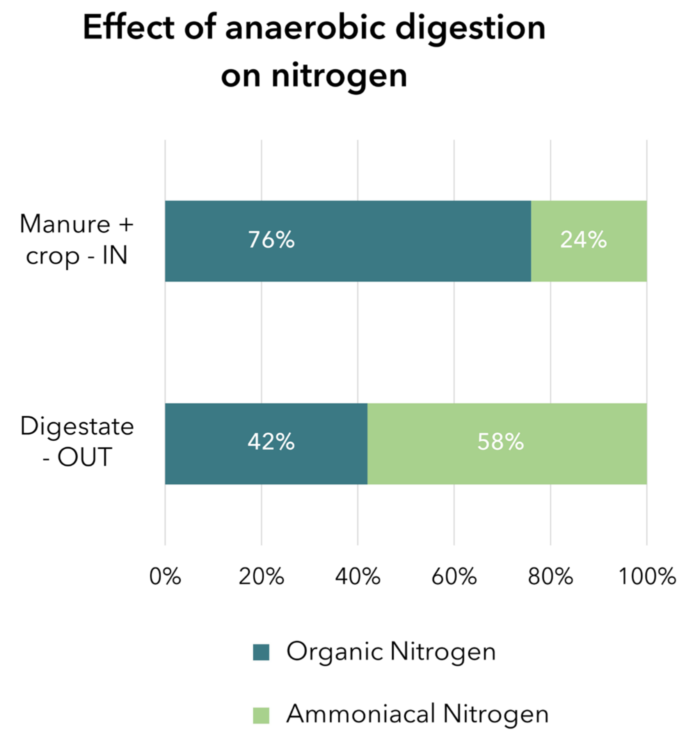


FIGURE 6 – Effect of anaerobic digestion on the nitrogen fraction of treated biomass (average values).

Moreover, anaerobic digestion using livestock effluents follows a very stable biological process and facilitates co-digestion with other organic matrices (by-products and sustainable crops), which are typically more nutrients deficient. All livestock effluents are technically suitable for anaerobic digestion; the only constraints may be the distance from the biogas plant and their performance in terms of energy generation (depending on water content and organic matter quality).

The recognised environmental benefits for livestock use and the technical suitability of the process are the reasons why, in view of the potential production of biomethane from agriculture in Italy by 2030, livestock effluents would be an essential feedstock for biogas plants.[7]

3.4 ORGANIC FERTILISATION WITH DIGESTATE

Unlike chemical fertilisation, which takes place essentially through NPK mineral elements, organic fertilisation – in addition to nutrients for crops – provides also microelements, probiotic substances, and organic carbon (C) whose stable form allows them to persist in the soil; it therefore contributes to increasing organic substance, which is essential to ensure soil fertility.

Compared to other organic matrices, digestate:

- Has much better hygienic-sanitary qualities than livestock effluents;
- Contains stabilised organic matter, whose carbon-to-nitrogen ratio (C/N) is generally very close to soil organic matter (8 to 14). Consequently, using digestate containing carbon - pretty resistant to degradation - and nitrogen in a similar proportion to soil organic matter favours the formation of stable humus without triggering the so-called "prime effect". This phenomenon, in fact, often occurs when only crop residues (having a C/N ratio between 50 and 100 and weak carbon) are added, which alone cannot guarantee significant and lasting increases in soil organic matter. This translates into a higher digestate humification index compared to other matrices (Table 2);
- Contains all macronutrients (nitrogen, phosphorus and potassium), in varying percentages depending on the source matrices. Compared to the nitrogen supply in input matrices, the total amount remains almost unchanged, but the ammonia fraction increases while the organic fraction decreases (Figure 6).

	C/N RATIO	HUMIFICATION INDEX (%)
CEREAL STRAW	70 - 80	22-30
STRAW RESIDUES	40 - 50	33-38
MANURE	30 - 40	40-50
MATURE MANURE	25 - 35	55-65
DIGESTATE	8 – 20	70-79

TABLE 2 – C/N ratio and humification index of the main materials buried in the soil for fertilising purposes (CIB elaboration based on its own data and different sources).

3.5 WHY GOING BACK TO WIDESPREAD ORGANIC FERTILISATION: SOIL FERTILITY AND CARBON SEQUESTRATION

The reasons supporting the need, or rather the urgency, to go back to widespread and enhanced organic fertilisation are countless and extremely important for agriculture and for countering climate change. In short (see bibliography for further details):

- A good supply of organic matter in agricultural soils is not only useful, but indispensable for agronomic and productive purposes because it ensures:
  - Regulation of nutrients and water cycles as well as better resilience;
  - Improvement of the physical structure of soil and soil stability (porosity, water retention capacity, etc.);
  - Increased soil biodiversity and related benefits (e.g. organic matter and nutrients turnover, pollutants degradation);
- The high risk of desertification due to the decrease of soil organic matter and consequently soil fertility has been repeatedly highlighted at European and global level, and Italy makes no exception. According to Prof. Rattan Lal, it is estimated that most cultivated soils have lost from 25 to 75% of their original organic matter;
- Increasing organic matter in agricultural soils is one of the most effective solutions for sequestering

[7] For detailes please see chapter 4

atmospheric carbon, as it also improves the fertility of cultivated land. The storage potential of soils is key because they are large carbon sinks on earth, about three times more than atmospheric carbon. Increasing soil carbon, even by a small percentage, can therefore significantly contribute to CO_2 removal from the atmosphere. Likewise, a loss of soil carbon would jeopardise ambitious climate change mitigation targets (e.g. the '4 pour mille' initiative launched in Paris during the 2015 COP 21).

Since soil is not a confined environment or sstatic system in in which to "store CO_2", it would be necessary not only to promote organic fertilization, but also to make sure that contributions outdo losses in order to combat desertification and achieve a positive soil carbon balance. In fact, even if losses were to be reduced (less tillage, soil coverage, etc.), they could not be eliminated tout court (natural soil respiration, etc.) (Figure 7).

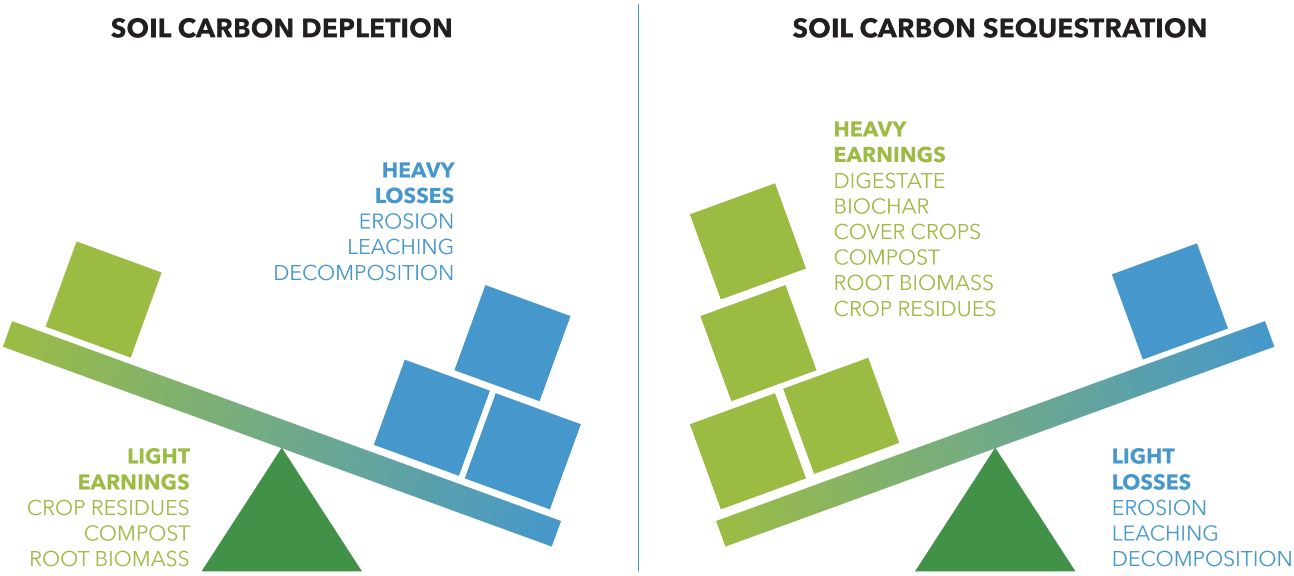


FIGURE 7 – The objective of organic fertilisation: inputs must exceed carbon losses (positive carbon balance - Source: Rattan Lal, 2020, modified)

3.6 COVER CROPS FOR ENERGY AND DIGESTATE FOR SOIL AS AN ALTERNATIVE TO GREEN MANURE

Including the so-called "double crops" (cover crops, catch crops) in crop rotation brings several indisputable advantages:

- Prolonged soil coverage with positive effects on biodiversity, with a clear reduction in losses due to leaching and particle run-off from soil surface, where fertility is higher;
- Reduction of nitrate leaching into groundwater. Growing crops in winter increases nutrient recycling;
- Preservation of soil fertility through crop rotation and the continued presence of roots and their exudates, both in the decay phase and in new formation;
- Less weeds and diseases and consequently less use of herbicides and pesticides.

It is no by coincidence that the introduction of cover crops is a practice adopted in organic farming and conservative agriculture and is part of the agro-environmental measures of current and presumably future RDPs.

The benefits of cover/catch(double) crops are therefore manyfold: they protect the soil from erosion and compaction and improve its structure and porosity; they promote nutrient recycling and limit nutrient losses; they facilitate weed and pest control; they bring nitrogen to crops; they increase soil organic matter and biodiversity. With an on-farm biogas plant, double crops serve the same purpose, although with two major differences:

- Additional crops, rather than being buried or mulched, are used for energy production, thereby preventing the GHG emissions that would have been released by fossil energy use;
- Soil fertility and soil organic matter are even better preserved because, in addition to having more roots (whose organic matter is particularly stable), organic fertilisation is regularly carried out with digestate, which, as pointed out above, has a higher humification index and a balanced C/N ratio.

With respect to cover crops, what has so far been overlooked, or rather not adequately highlighted, is the positive effect in terms of the overall CO_2 balance. To boil it down to a few conservative values, Figure 8 shows that at least 8-10 t/ha of CO_2 are spared per hectare of land covered with a second crop for biogas.

Through anaerobic digestion, the CO_2 removed from the atmosphere is then transformed into biomethane and stable carbon in soil. In fact, by using digestate as a fertiliser and through crop roots, around 0.5-1.0 t/ha of stable carbon is returned to the soil every year, bringing many positive effects, as confirmed by multiple scientific papers (see bibliography at the end of this report).

As explained in greater detail below, the three pillars of Biogasdoneright® match three of the ten fundamental actions described later, which are necessary to effectively impact CO_2 emission reductions and agricultural activity in general.
Last but not least, increased diffusion of double crops, supplying more soil organic matter, and minimum tillage, are all actions to preserve and increase biodiversity.

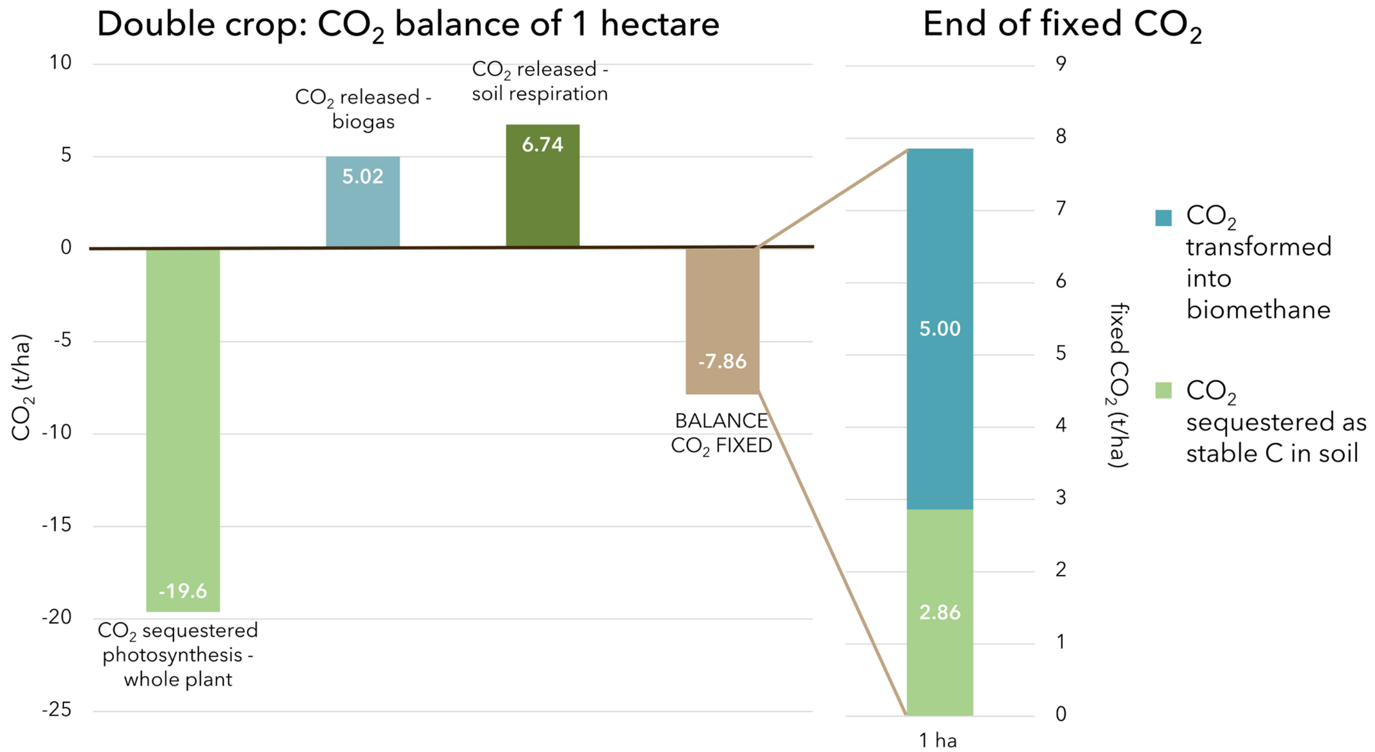


FIGURE 8 – Example of simplified CO_2 balance of 1 hectare of additional crop considering a precautionary crop yield of 8 t/ha of dry matter and fertilization with the digestate generated by it considering a precautionary humification index (40%), similar to that associated with manure.

4. THE ROAD MAP OF THE ITALIAN AGRICULTURAL BIOMETHANE BY 2030

4.1 THE POTENTIAL OF BIOGAS/BIOMETHANE BY 2030

It is estimated that by 2030 Italy could **produce 6.5 billion cubic metres of biomethane** from agricultural and agro-industrial biomass for various purposes (electricity, transport, industrial applications), thereby making farms more competitive and financially and environmentally sustainable (Figure 9).

To develop the potential of biogas from agriculture in Italy, it would be necessary to:

- Limit first crops, in line with the specific characteristics of Italian agriculture. A reduction in the utilised agricultural area is expected with respect to the current levels (less than 200,000 ha, i.e. 3% of the Italian UAA) – which are anyway lower than the area once set aside. Moreover, greater attention will be paid to individual territorial contexts. Allocating part of farmland to sustainable crops for biogas helps preserve crop rotation for food and also enhance soil that is difficult to use due to type, structural lack of organic matter and / or adverse seasonal climatic trends;
- Intensify the use of double crops - considering the characteristics at local production chains as well as irrigated or irrigable UAA - on an area not exceeding 10-12% of the UAA used for arable crops;
- Use livestock manure in anaerobic digestion, an imperative to drastically reduce the overall impact of Italian livestock farming and at the same time improve organic fertilization and soil fertility. It is estimated that by 2030 at least 65% of the livestock manure produced today will be used for biogas;
- Use crop residues; in addition to those already included in animal manure it is estimated that not more of 10 to 15% of all crop residues will be used

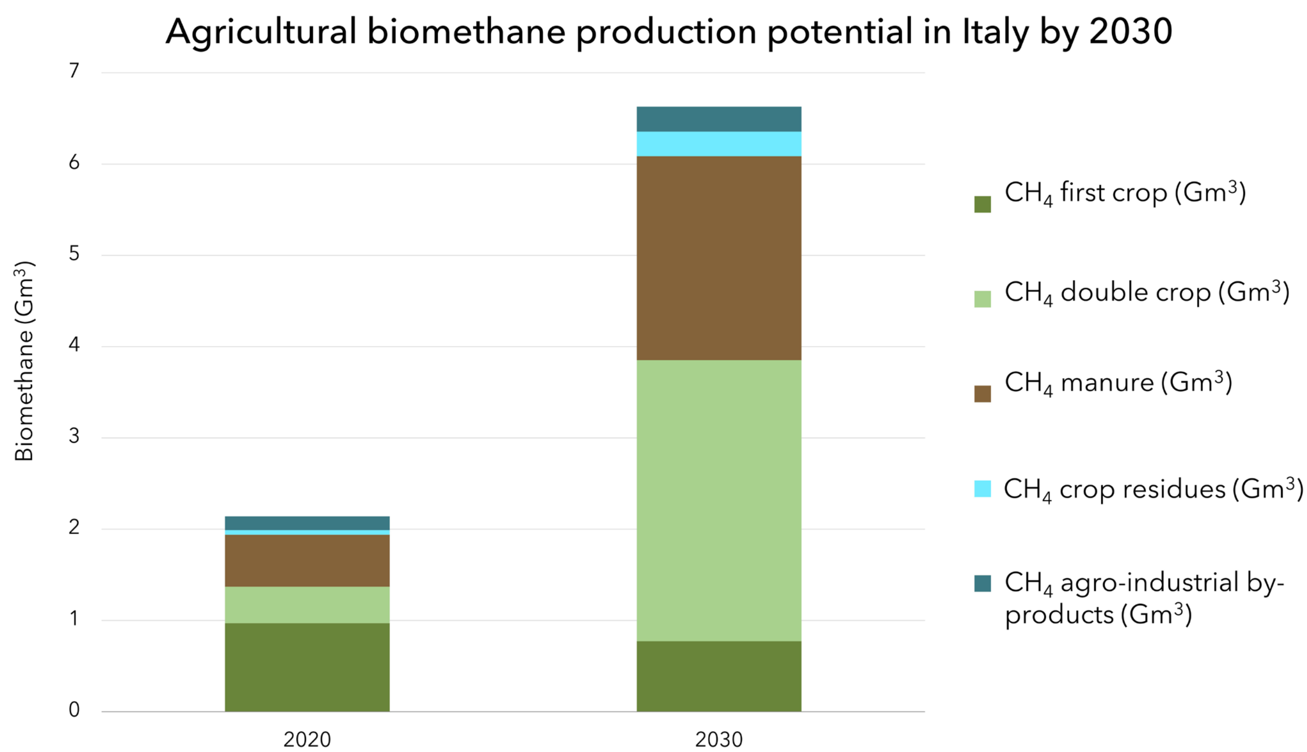


FIGURE 9 – Italian agricultural biogas roadmap to 2030: 6.5 billion cubic metres of biomethane for varius purposes.

for biogas. As for crop residues, once removed they will be compensated by digestate - which has a better humification index.

- Use high-quality agro-industrial by-products, handled according to the principles of the circular economy. Depending on their quality and valorisation in the food chain, it is estimated that 10 to 70% of all available by-products will be used for biogas.

In summary, the analysis on the type and relative quantity of biomass that might be needed, confirms that an overall production potential of 6.5 billion cubic meters of agricultural biomethane by 2030 is feasible thanks to a properly weighted use of resources and soil (Figure 10).

4.2 SUSTAINABILITY OF BIOMETHANE AS A "RENEWABLE SOURCE"

In terms of "sustainability" of agricultural biomethane as a "renewable source", two applications are currently possible (transport and electricity), but it is now generally acknowledged that industrial use (cooling/heating and biomethane as feedstock) should also be included in the mix.
To be precise, according to the Renewable Energy Directive (RED and the adopted RED II as well) only "sustainable" renewable sources can be used to reach the European target on production from renewable sources.
The Italian 2030 development strategy for biogas from agriculture – considering the above - can guarantee:

- The production of sustainable and advanced biomethane volumes for transport to meet specific national targets;
- The production of sustainable biomethane for uses other than transport (electricity, industrial uses), since it is compliant with sustainability criteria in terms of CO_2 eq. savings set out by the EU Directive 2018/2001 (RED II).

It should be noted that bioenergy is "sustainable" when the land used for growing crops complies with specific requirements (according to art. 29 of the RED II) and when CO_2 eq. emissions released by production are lower by a significant and predetermined percentage (depending on use: transport, electricity, heating/cooling) than the so-called "fossil fuel comparator (FFC)"; scope, criteria to be met and emission savings to be guaranteed are indicated in the above-mentioned European legislation and summarized in Table 3.

By 2030, therefore, the production of biomethane from the above-mentioned biomasses will result in significant savings of CO_2 eq. emissions due to the phasing out of fossil energy, as further outlined below.

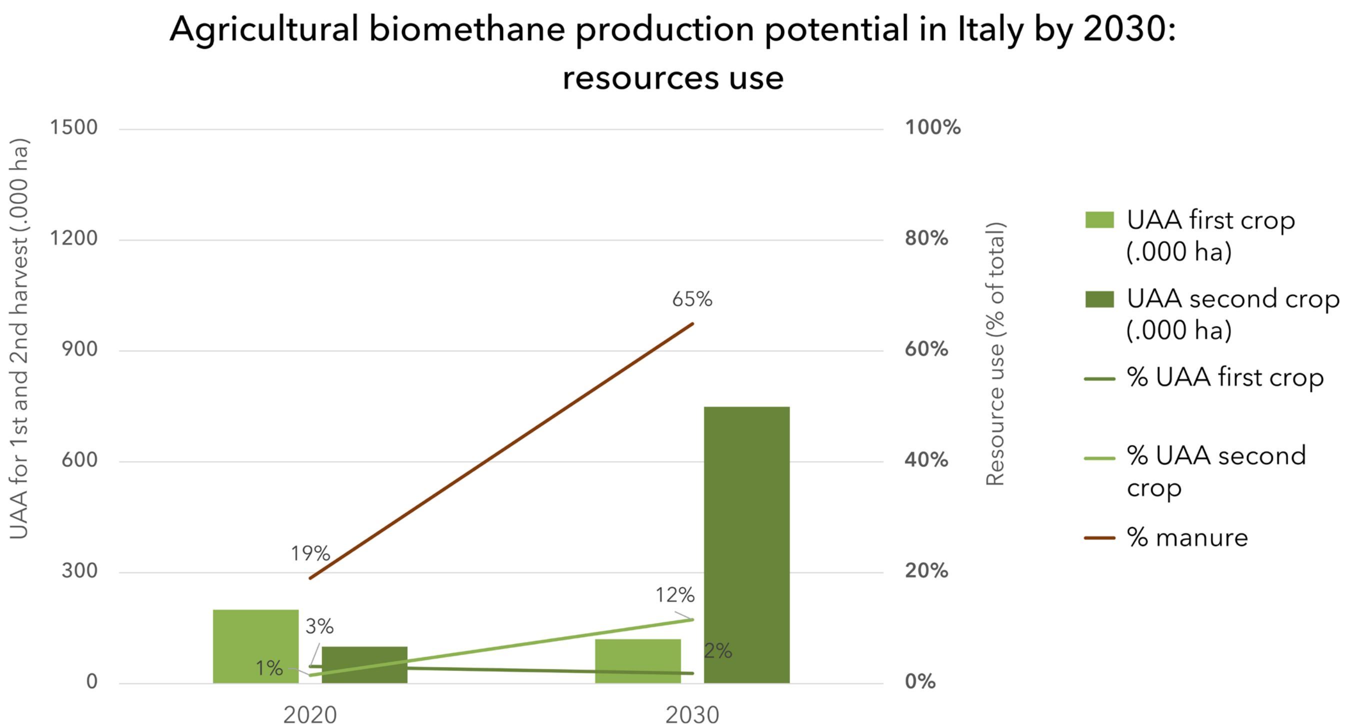


FIGURE 10 – Italian agricultural biogas roadmap to 2030: resources use.

	DIRECTIVE 2009/28/EC	DIRECTIVE EE 2018/2001
BIOGAS – BIOMETHANE FOR TRANSPORT		
FOSSIL FUEL COMPARATOR	83.8 g CO_2 eq. /MJ	94 g CO_2 eq. /MJ
SAVINGS TO BE GUARANTEED [1]	60%	60% ; 65%
BIOGAS FOR ELECTRICITY, HEATING/COOLING [2]		
FOSSIL FUEL COMPARATOR	Not planned	183 g CO_2 eq. /MJ electricity 80 g CO_2 eq. /MJ heating
SAVINGS TO BE GUARANTEED [3]	Not planned	70% (from 2021) ; 80% (from 2026)

TABLE 3 – Fossil fuel comparator and GHG emission savings to be guaranteed in relation to biogas destination and reference legislation.

[1] GHG emission seving must be at least 60% for biogas/biofuels produced in plants in operation from 6 October 2015 to 21 December 2016 and 65% for plants in operation from 1 January 2021.

[2] EC Directive 2009/28 does not include sustainability criteria for electricity from biomass. Instead, EU Directive 2018/2001 introduces compliance with sustainability criteria for plants producing electricity from biogas with a total rated thermal input equal to or exceeding 2 MW from 1 January 2021.

[3] The GHG saving must be at least 70% for electricity, heating and cooling production from biogas used in installations starting operation from 1 January 2021 until 31 December 2025, and 80 % for installations starting operation from 1 January 2026.

5. FARMING FOR FUTURE: OUR PROPOSAL

5.1 THE 10 ACTIONS FOR A "CLIMATE POSITIVE" FARMING

Italian agriculture is responsible for about 9% of GHG emissions of the whole country and like all productive sectors must contribute to reduce its environmental impact. Current knowledge, techniques and technology confirm that the "actions" to make this happen are known, feasible and with proven efficiency and effectiveness.

According to the path and methods previously described, combining biogas as energy with high-quality food production – so typical from our country – will help farms take most of the necessary actions to reduce climate-altering emissions, thereby having a further positive effect on the environment: restoring soil fertility by increasing the supply of stable organic matter.

Hence our proposal: FARMING FOR FUTURE: TEN ACTIONS TO FARM THE FUTURE.

ACTION 1
RENEWABLE ENERGY IN AGRICULTURE

- Electrifying energy end-uses wherever possible by promoting the production of electric agricultural machinery;
- Promoting on-farm cogeneration of electricity from biogas and/or solar energy;
- Developing biomethane mechanisation (also with Bio-LNG), using biomethane in high-efficiency CHP and for all engines and uses that are hardly electrifiable.

ACTION 2
FARM 4.0

- Promoting process digitalisation, precision farming, robotics and IoT (Agriculture 4.0, Livestock farming 4.0) and all those techniques and technologies that regulate the use of resources depending on soil characteristics and the specific needs of crops and livestock (energy, fertilisers, plant protection products, herbicides, water).

ACTION 3
MANAGEMENT OF LIVESTOCK MANURE

- Using more livestock manure for anaerobic digestion (65% by 2030), in addition to crop residues and agro-industrial by-products;
- Providing and recovering biogas from digestate storage for a volume at least equivalent to the first 30-day production;
- Covering the remaining storage for further emission reduction with volumes that guarantee distribution when suitable in terms of nitrogen efficiency.

ACTION 4
ORGANIC FERTILISATION

- Optimising and promoting organic fertilisation with a targeted use of digestate instead of chemical fertilisers, increasing awareness about the specific characteristics of digestate compared to livestock effluents and synthetic fertilisers and increasing the efficiency of the readily assimilable nitrogen contained therein;

ACTION 5

INNOVATIVE AGRICULTURAL PRACTICES

- **Adopting minimum tillage techniques (minimum tillage, strip tillage, no tillage);**
- **Adopting low-emissivity and high-efficiency digestate distribution methods and settings in the field: low-emissivity distribution, burial, distribution under cover;**
- **Breaking down transport from distribution to optimise entry time into the field;**
- **Constructing underground digestate transport networks and decentralised storage facilities;**
- **Promoting fertigation with clarified and micro-filtered digestate (by means of different irrigation systems, including subsurface drip lines).**

ACTION 6

QUALITY AND ANIMAL WELFARE

- **Selecting animals with high production performance as a result of continuous genetic improvement;**
- **Adopting housing and herd management techniques in line with animal welfare principles and Livestock farming 4.0 systems;**
- **Adopting innovative feeding protocols to reduce bovine enteric fermentation and excreted nitrogen;**
- **Selecting hybrids and fodder varieties as a result of continuous genetic improvement.**

ACTION 7

INCREASING SOIL ORGANIC MATTER

- **Extending double crop areas in crop rotations, including nitrogen-fixing crops, either alone or in combination with graminaceous plants;**
- **Minimising tillage (conservation farming practices);**
- **Implementing and promoting regular, targeted and adapted organic fertilisation with digestate.**

ACTION 8

AGROFORESTRY

- **Incorporating woody crops into regular crops to create sylvicultural systems and to increase photosynthesis per unit area to have more biomass available for processing.**

ACTION 9

PRODUCTION AND USE OF BIOBASED MATERIALS

- **Increasing production of biogenic materials and biochemicals (from wood used in construction to biobased products for various uses).**

ACTION 10

BIOGAS AND OTHER RENEWABLE GASES

- **Reusing CO_2 to produce synthetic fuels: producing methane from the biogenic CO_2 in biogas and electrolysis-induced H_2 powered by renewable energy (Power-to-gas), producing renewable H_2 from the biomethane steam reforming process.**

Among the actions described above, the first eight are linked to decisions on investments in the agricultural sector, while the last two depend on the ability of the industry, particularly the gas industry, to develop industrial transformation structures (carbon reuse) for methane use in areas difficult to electrify, especially hydrogen supply chains, and possibly CO_2 capture and sequestration.

The synergy between these two productive worlds is key to maximize "the reuse and long term sequestration of CO_2 of biogenic origin" captured from the atmosphere via photosynthesis, thanks to the eco-intensification of production in agriculture.

With respect to agriculture, many of the actions described above specifically regarding agricultural activity have a positive impact on the biodiversity of agro-ecosystems (more rotations, more soil organic matter, agroforestry, synthetic input reduction), as well as on greenhouse gases and ammonia; in addition, several other pollutants will also be abated. (Figure 11). In fact, as described above, the management of livestock effluents and their distribution in the fields represent the main emission source of GHGs and ammonia.

Finally, most of the actions are directly (action 1, 3, 4, 5 and 7) or indirectly (actions 2, 6 and 8) linked to on-farm anaerobic digestion plants. Besides, these are also the actions with more positive effects in terms of CO_2 eq. emission reductions.

ACTION		GOALS	AFFECTED EMISSIONS	TYPE OF ACTION
1	Renewable energy in agriculture	Increasing the use of renewables instead of fossil fuels until they are fully replaced Reducing energy intensity per product unit (energy efficiency).	CO_2 ↓↓↓	MITIGATION
2	Farm 4.0	Reducing the amount of resources used per product unit generated Maximising the efficiency of the resources used	CO_2 ↓↓ N_2O NH_3 ↓↓ CH_4 ↓	
3	Management of livestock manure	Reducing emissions from livestock management and effluent treatment Exploiting residues and by-products Producing biogas	CH_4 ↓↓↓ N_2O NH_3 ↓	
4	Organic fertilisation	Avoiding the production of synthetic fertilisers (primarily urea) Recycling of nutrients	CO_2 ↓ N_2O ↓↓	
5	Innovative agricultural practices	Reducing losses of organic matter Distributing digestate when crops need it Maximising the efficiency of distributed nitrogen and nutrient recycling Reducing the use of synthetic fertilisers	CO_2 ↓↓ N_2O NH_3 ↓↓	
6	Quality and Animal Welfare	Increasing productivity Reducing resource use per product unit Improving animal welfare	CO_2 ↓ CH_4 ↓↓	
7	Increasing soil organic matter	Increasing photosynthesis per hectare through double cropping, increasing root production Increasing the amount of digestate that will be returned to the soil Increasing the amount of stable organic carbon in the soil through a positive balance between total inputs and oxidation losses Enhancing the chemical, physical and biological fertility of the soil	- CO_2 in the atmosphere + C stable in soil	CAPTURE
8	Agroforestry	Increasing photosynthesis per hectare Increasing root production Producing wood for various purposes	- CO_2 in the atmosphere + C stable in soil	

FIGURE 11 – Effects of the actions on GHG and ammonia reduction.

5.2 2030 ORGANIC FERTILISATION ROADMAP

Before drawing some conclusions on the outcomes that the integration of biomethane - produced according to the principles of Biogasdoneright® - could bring in terms of emissions reduction, along with the actions described above, an aspect of considerable agronomic and environmental importance should be highlighted: the possibility of extending organic fertilisation (as a partial or total replacement for chemical fertilisation) over a larger area of cultivated land (at least 40% more than with livestock manure alone - Figure 12) thanks to the production of digestate.

By 2030, the use of double crops (which otherwise would not have been grown) in co-digestion with livestock effluents, residues and by-products for biogas will produce 'more digestate', thus allowing organic fertilisation to be decoupled even where there is no livestock.

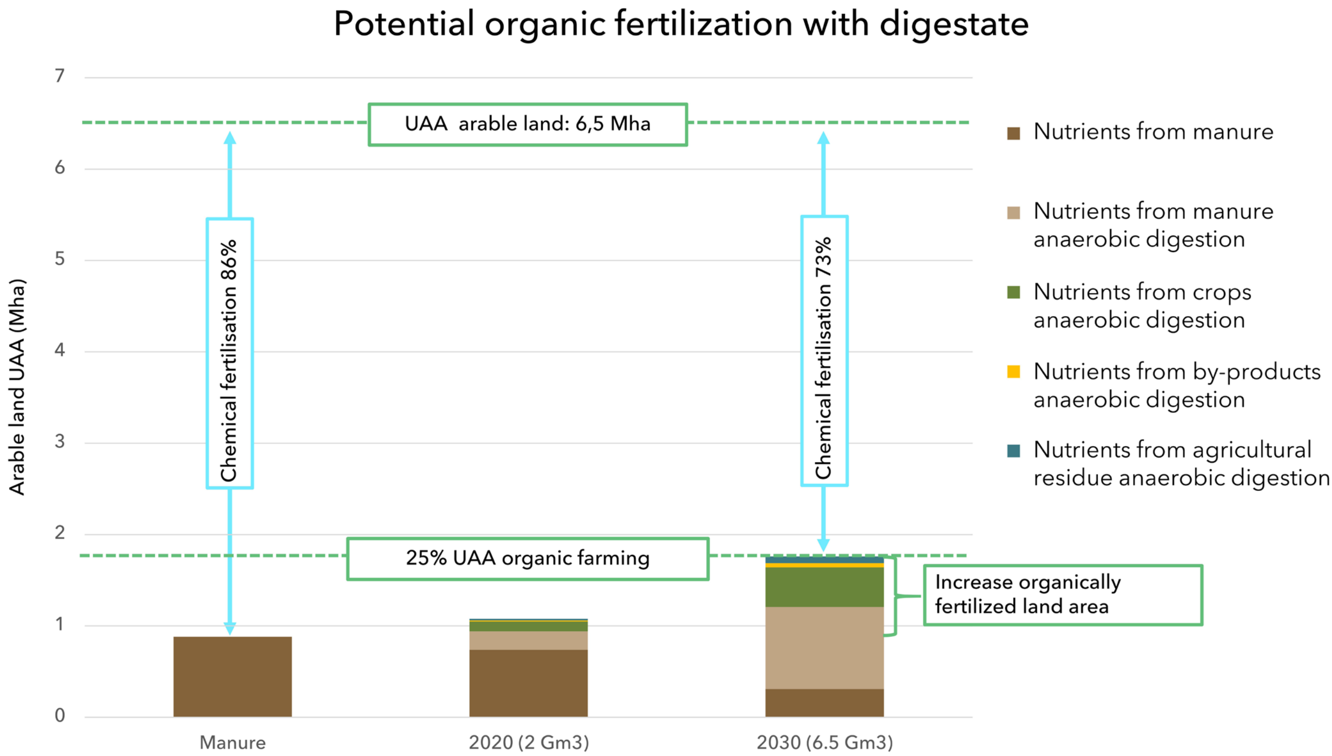


FIGURE 12 – Simplified estimate of the UAA that can be fertilised with livestock manure only and with livestock manure and digestate assuming the distribution of 220 kg/ha of TKN (Source: CIB elaboration on different sources, 2020)

The qualitative features of digestate and the advanced methods for distribution in the field will also lead to an increasing efficiency of distributed nutrients, primarily, but not exclusively, nitrogen.

In other words, in a general context where the risk of soil desertification has been widely acknowledged and reducing the use of synthetic fertilisers is recommended, the increased availability of a valuable new organic fertiliser and nutrient recycling need to be properly recognised, along with their positive effects in terms of GHG emission reductions.

5.3 IMPACT ON GHG EMISSIONS

The estimated reduction in greenhouse gas emissions as a result of the measures described above takes into account the potential production of biomethane as described in point 4 and the most recent scientific evidence on the processes involved; in any case, such estimates must be considered as conservative.
As to 2030 and the official 2018 ISPRA data for the agricultural sector, Table 4 shows the effects of the ten actions described above, distinguishing and highlighting first of all those that can be carried out directly by farms: mitigation actions (emission reductions: actions no. 1 to no. 6) and sequestration actions (CO_2 captured and sequestered as stable carbon fixed in the soil: actions no. 7 and no. 8).
On the other hand, it is difficult for multiple reasons to quantify the effects induced by the actions involving industry (actions no. 9 and no. 10), which depend on the grid gas greening and the production of bio-based products and the quantity of biogenic CO_2 of raw biogas reused or sequestered in biobased materials or elsewhere. Therefore, no specific estimates are currently available.

With respect to CO_2 eq. emissions specifically, the actions to be carried out by the agricultural sector can result in the following:

Direct carbon dioxide emissions
As technologies for the production and use of renewable energy become more common (including mechanization powered by Bio-LNG or Bio-CNG, or renewable hydrogen), up to 90% of fossil energy can be replaced; by 2030 a 30% replacement rate is expected.
Conversely, a 20% reduction of CO_2 released by urea is expected thanks to organic fertilization with digestate, which is more effective due to higher soil fertility, the promotion of precision farming and a regulatory framework disincentivising urea use. Finally, a growing production of synthetic fertilizers using renewable carbon and hydrogen might also be an option.

Methane emissions
- Enteric fermentation: it is estimated that promoting precision feeding techniques, along with the genetic improvement of livestock and the digestibility of feed, should result in a 5% reduction by 2030;
- Livestock effluent management: anaerobic digestion is the optimal solution; therefore methane emission reductions are proportional to the methane recovered from digested effluents: 65% in 2030;
- Rice cultivation: reduction is the result of dry rice production with no submergence;
- On-field residues combustion: the expected

		2018	2030		
		kt CO_2 eq.	Red. %	Rid kt CO_2 eq.	kt CO_2 eq.
CO_2	Energy use	8,247	-30%	-2,474	5,773
	Liming	15	-30%	-5	11
	Urea	405	-20%	-81	324
CH_4	Enteric fermentation	14,202	-4%	-625	13,577
	Manure management	3,480	-65%	-2,276	1,204
	Rice cultivation	1,553	-5%	-78	1,475
	Field burning of residues	15	-30%	-5	11
N_2O	Manure management	2,190	-37%	-804	1,387
	Agricultural soils	8,322	2%	207	8,529
	Field burning of residues	4	-30%	-1	3
CO_2 NEGATIVE EMISSION	Soil carbon sequestration	--	--	-3,109	-3,109
	Agroforestry	--	--	-2,935	-2,935
	Renewable gases wit CCS	--	--	--	--
	Biobased materials	--	--	--	--
TOTAL		**38,434**	**-31.7%**	**-12,185**	**26,249**

TABLE 4 – Estimated reduction of GHG emissions by 2030 following the implementation of mitigation and CO_2 sequestration actions relevant to integrated agriculture with biogas production (with 65% of the livestock manure produced in Italy to anaerobic digestion).

recovery of crop residues, including straw as a co-substrate for digestion, helps limit combustion in the field. A 30% reduction is estimated by 2030.

Nitrous oxide emissions

- Livestock effluent management: reductions from this source (estimated at 37% by 2030) results from the use of livestock effluents and shovelable fractions specifically for digestion and from the lower equivalent production of separated solid digestate (digestion reduces the organic fraction by more than 50%);
- Soil emissions remain substantially unchanged as they are increased by the higher nitrogen inputs required by double-cropping, but record some reductions for multiple reasons, including the greater nitrogen efficiency of digestate, precision farming techniques, etc.

Negative emissions

- Soil carbon sequestration: it relies on the greater potential for carbon storage in soil through the root systems of additional double crops and the resulting greater availability of digestate. With respect to the digestate humification index (higher on average than other organic materials), a conservative 25% value was estimated. It is likely that conservation agriculture techniques would be applied to 10% of arable land by 2030. The total potential for soil sequestration in 2030, combined with the use of livestock effluents, is equivalent to 848 kt of carbon, resulting in a 3,109 kt CO_2 reduction from the atmosphere;
- Agroforestry: it is estimated that by 2030 there will be a poplar grove of approx. 45,000 ha and 40 trees/ha will be planted on an arable area of approx. 200,000 ha. The main benefit would not only be wood production for the wood industry,

but also more organic substance stored in deeper soil layers, which are not affected by tillage. By 2030, the overall potential for soil sequestration will be equivalent to 800 kt of carbon, resulting in a 2,935 kt CO_2 reduction in the atmosphere.

Finally, as to the 2030 GHG emission scenario (Table 5, Figures 13 and 14), by integrating biomethane in line with the principles of Biogasdoneright® and adopting the solutions and techniques previously described, the Italian agriculture:

- Will go from an overall emission level of about 38,400 kt of CO_2 eq. in 2018 to just over 26,000 kt, thanks to direct investments, thereby reducing its impact by 32% overall. This reduction will be the result of both mitigation measures and CO_2 sequestration activities in soil;
- Biomethane will further contribute to reduce CO_2eq. emissions nationwide by 19,000 kt more approx., thanks to the phasing out of fossil energy; compared with 2018, this translates into a 6% reduction of Italian CO_2 eq. emissions released by fossil energy.
- Thanks to the investments from farmers, the combined effect of reducing direct emissions in farming and mitigating emissions in the energy sector (by producing biomethane from agricultural biomass) will result in an overall reduction of 31,500 kt of CO_2 eq., i.e. 80% of the current emissions of the Italian agricultural sector (Figure 15).

	2018	**2030**
Agriculture emissions	**kt CO_2 eq.**	
Emissions from agricultural activities	38,434	32,293
Soil carbon sequestration and agroforestry	0	-6,044
Balance sheet for agriculture	**38.434**	**26.249**
Emissions savings (%)		-32%
Biogas use	**kt CO_2 eq.**	
Avoided emissions (non-use of fossil fuels)	--	-19,276
Avoided emissions balance	**--**	**-19,276**

TABLE 5 – Overview of the estimated savings of CO_2 eq. emissions from agriculture in 2030 due to the implementation of mitigation and sequestration actions compared to the year 2018 and the emissions avoided by not using fossil fuels.

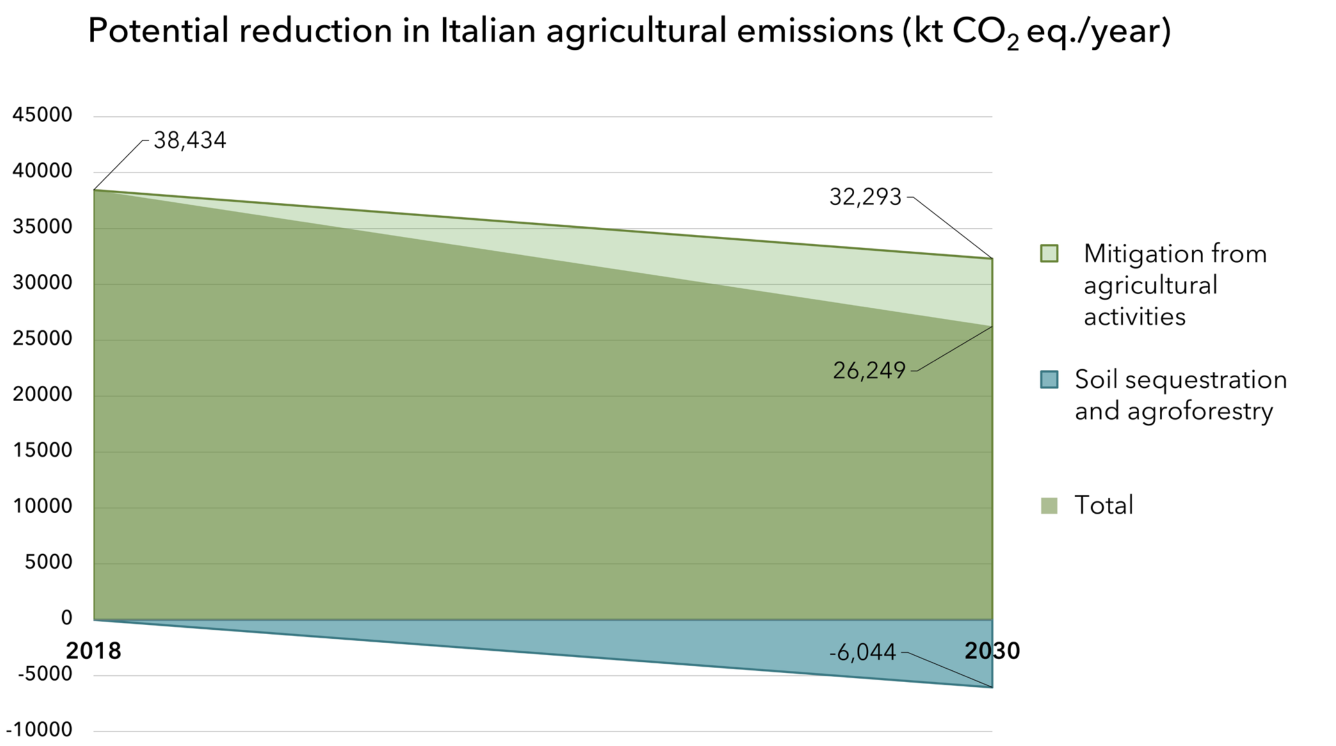


FIGURE 13 – Potential reduction of CO_2 eq. emissions from Italian agriculture due to the solutions of mitigation (no. 1 to no. 6) and sequestration (no. 7 and no. 8) actions.

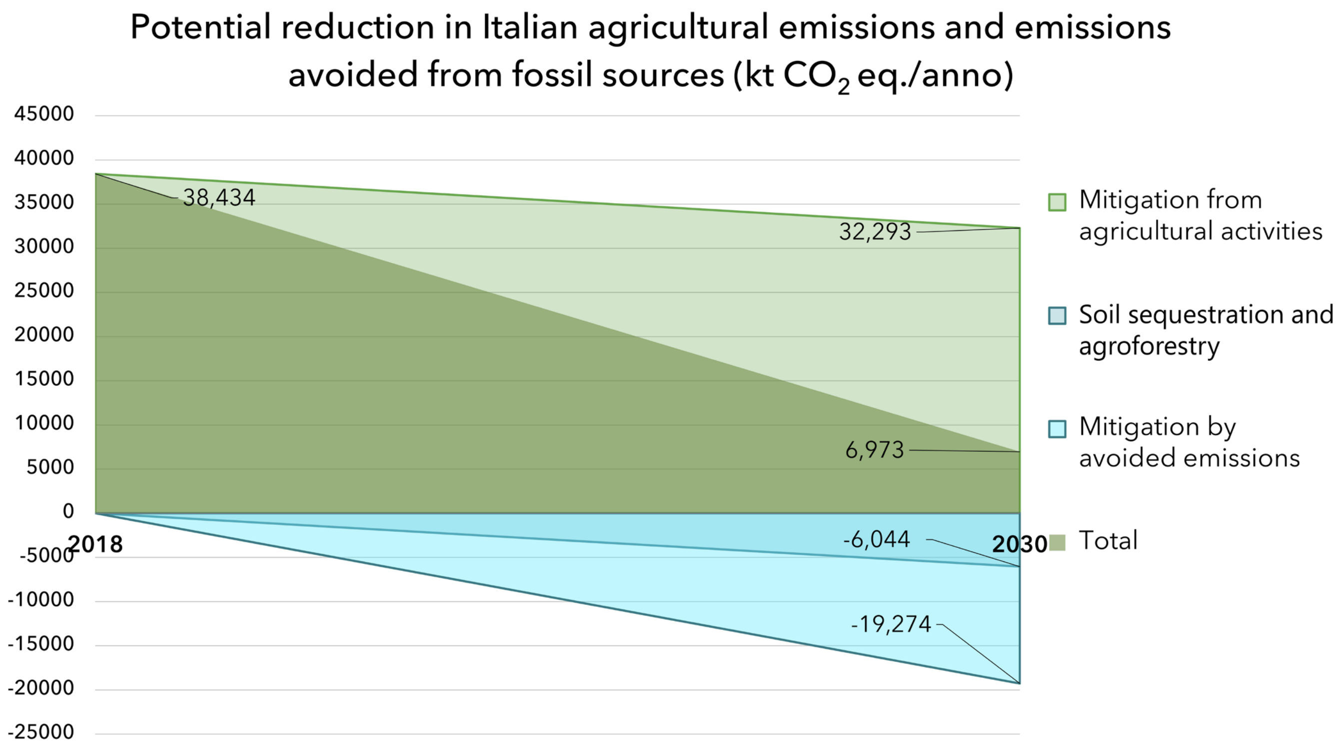


FIGURE 14 – Potential reduction of CO_2 eq. emissions from Italian agriculture due to the solutions of mitigation (no. 1 to no. 6) and sequestration (no. 7 and no. 8) actions and avoided emissions from the non-use of fossil fuels.

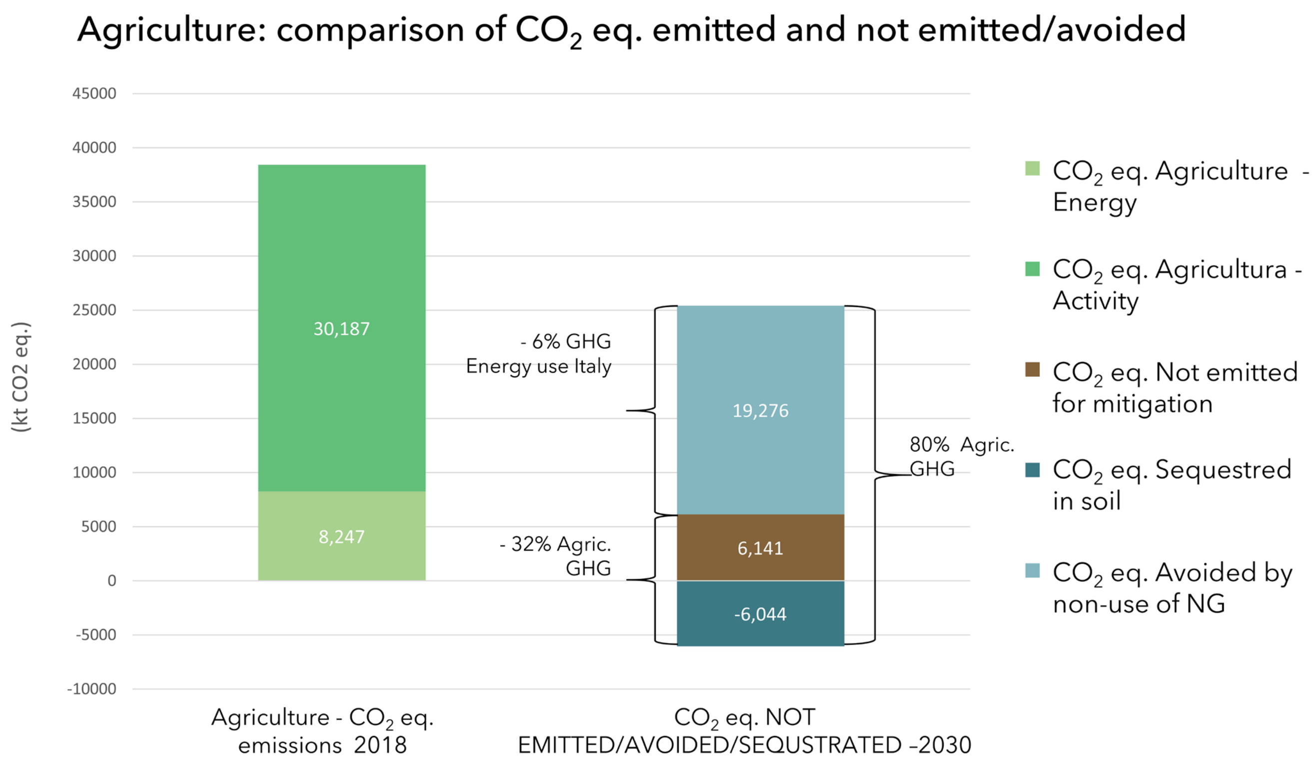


FIGURE 15 – Farming for future: comparison between agriculture's emissions in 2018 and the CO2eq. emissions on which agriculture can positively act in 2030. The adoption of innovative and virtuous breeding and cultivation systems together with the return to organic fertilization will reduce agricultural emissions by 12 Mt of CO2eq. In addition, the simultaneous production of biomethane from agricultural biomass according to the principles of Biogasfoneright® will lead to an additional 19 Mt of CO2 eq. avoided to the national energy sector, thanks to the non-use of fossil fuels.

CONCLUSIONS

In conclusion, in the near future farms will soon be able to implement the agro-ecological conversion of their activity by integrating anaerobic digestion, provided that the right regulatory framework and specific targets are set along with adequate economic support.

Should the overall framework be clear, thereby allowing for the bankability of investments, farmers would be ready to invest in innovation "from the field to the plant" (facilities, ICTs, agricultural machinery, ...), as they have already done in the past; this way environmental indicators will confirm that they have taken the right path towards environmental sustainability.

Access to a suitable energy market (biomethane as renewable energy for multiple uses) combined with the EU resources allocated through the Recovery Fund and the new CAP are all key to the success of such "agricultural revolution".

The promotion of a sustainable (i.e. carbon neutral in a net zero and then net negative scenario) and high-quality agriculture, respecting the environment and the biodiversity of our agro-ecosystems and focusing on agricultural soil fertility, are the main messages that Italian farmers can give in terms of food supply differentiation on domestic and international markets; moreover, it is also key in stimulating the export of technologies in which Italian manufacturing has always excelled globally (agricultural machinery, gas industry technologies).

Likewise, the gradual decarbonisation of the gas grid with increasing shares of renewable gas (from biogenic sources and others as hydrogen) is not only important for a faster and cost-effective energy transition, but also to promote more sustainable, competitive and innovative farming in valuable food markets.

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