ARTFuels

POSITION PAPER

Biogas Done Right in transport

The sustainable way to produce food, feed and biomethane[1]

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Abstract

Agriculture and traffic are among the largest sources of GHG emission with 12% resp. 14% of global emission. Any process to reduce emission from the two sources is actually an urgent need. Biofuels and agriculture are naturally closely related and therefore a combined action to improve sustainability of agriculture and traffic is the recommended way to take. Bioenergy is a controversial issue, questioned by many scientists and policymakers. Many among them believe that there is no way to produce organic carbon for bioenergy without harming environment and direct or indirect impact on food and feed availability. However, with today's agricultural technologies integrating biogas production, sequential cropping and precision farming we can produce GHG neutral or even GHG negative BioEnergy while Capturing and Sequestering Carbon (BECCS); without limiting food and feed production and with a low risk of indirect land use change (iLUC). This concept called Biogas Done Right has been proven by Italian farmers motivated by the Italian Biogas Association.

[1] See also the ARTFuels' position paper http://artfuelsforum.eu/wp-content/uploads/2018/05/ART-Fuels-Forum_BiogasDoneRight_Position-Paper_May_2018-1.pdf

The Biogas Done Right concept

Figure 1 shows the basic concept of Biogas Done Right (BDR). It follows essentially the idea of closing the CO2-cycle however, there are two differences to the classic digestion of agricultural residues, by-products and energy crops: The major difference is the integration of multiple cropping where the primary crop (cash crop) serves for food or feed while the secondary crop can be used for energy production together with the animal manure and other agricultural or agro-industrial by-products. The second difference is the full recycling of the digestate as fertilizer recovering mineral nutrients and recycling very stable carbon to the soil. Additional practices such as no- or strip-tillage, precision application of digestate, etc. can further enhance the positive environmental outcome and improve farm economics.

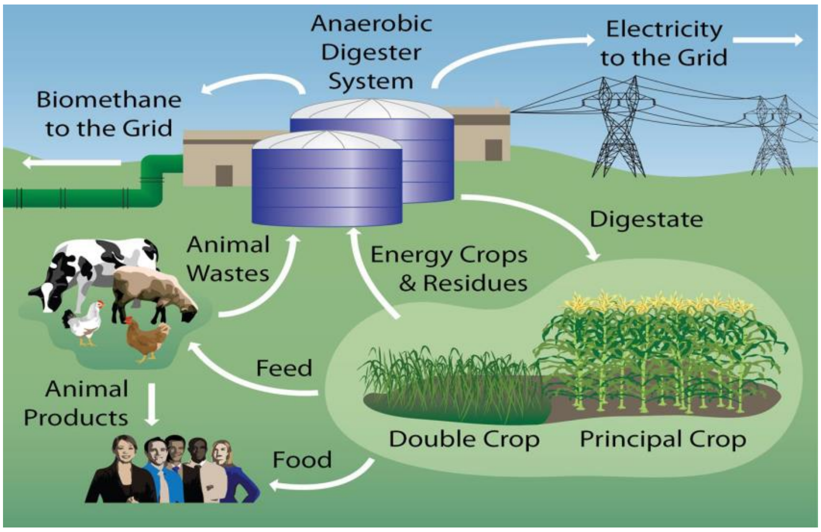

Figure 1. the basic concept of Biogas Done Right

The BDR concept includes:

- Production of sustainable biomethane[2] from animal manure, agricultural residues and agro-industrial by-products;
- Double cropping with a primary crop for food or feed and a secondary crop for energy production with crop rotation;
- Year-round covered soils avoiding soil erosion and nitrogen emission (air emission and leaching), enhancing soil structure and organic carbon content;
- Shift from deep plowing and chemical fertilization to precision farming with minimum tillage (strip tillage, no tillage) to conserve soil carbon and soil moisture;
- Regular use of digestate as organic fertilizer, increasing fertility and soil carbon content (minimized input of chemical fertilizers);
- Optimized fertilization with drip fertigation (combined fertilization and irrigation on growing fields);

[2] When biogas – a mixture of carbon dioxide and methane - is used for injection into the gas grid and ultimately as a vehicle fuel, it has to be upgraded to natural gas quality. Essentially this means removal of CO_2. The product is called biomethane

The Biogas Done Right concept

- Include the growth of legumes to fix nitrogen and temporary grass to reduce N2O emissions;
- Reduce the fossil fuel consumption for farming by using biomethane.

Energy production and sequestering carbon without lowering food & feed production

Biogas is produced for two major reasons: energy production and production of organic fertilizer and soil improver. Biogas can be transformed to electricity and heat in a combined heat and power plant or preferentially be upgraded to biomethane in natural gas quality that can be first injected into a gas grid and distributed or directly be used as vehicle fuel.

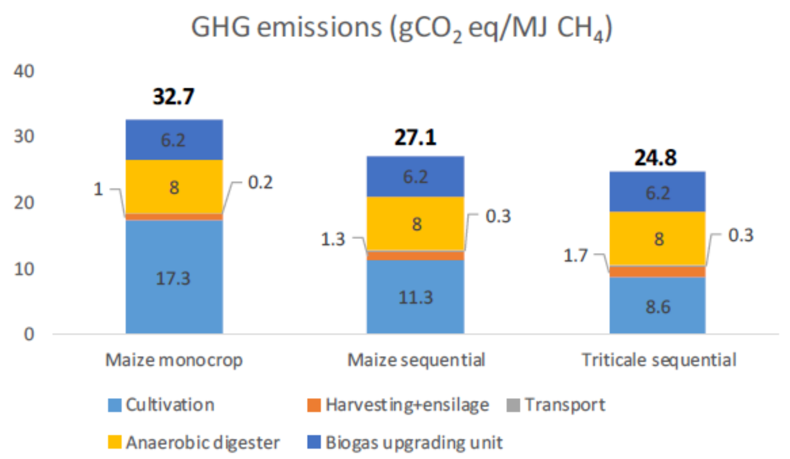

Fig. 2. Effect on GHG emission reduction by double cropping

Use of manure to produce biogas not only results in renewable energy and fertilizer but also avoids significant methane and nitrogen dioxide emissions when compared to conventional agriculture under the premises that the storage tank of the digestate is covered. Therefore, biogas produced from anaerobic digestion of manure generates an emission credit of -111.9 gCO_{2eq}/MJ according to JRC[3]. An additional GHG reduction of up to 24% is achieved by sequential cropping (Fig. 2)[4]. The main difference in emissions between mono-crops (maize) and sequential crops (maize and triticale) stems from the cultivation stage; in case of sequential cropping agricultural machinery and pesticides are used to a lesser extent and no synthetic fertilizer is used, compared to the mono-cropping practice.

The growth of agricultural crops for biofuels can lead to indirect land use change effects due

[3] Solid and gaseous bioenergy pathways: input values and GHG emissions, JRC, 2014, Report EUR 26696 EN
[4] https://www.ecofys.com/files/files/ecofys-2016-assessing-benefits-sequential-cropping.pdf

Energy production and sequestering carbon without lowering food & feed production

to the risk that existing food and feed production is displaced by bioenergy production. ILUC effects do not take place either if no agricultural land is used to produce biofuel feedstock or if agricultural land is used while maintaining existing food or feed production on the land. This means that ILUC risks for energy crops can be avoided if biomass for energy is produced additionally to the existing production of food or feed on the same land.

Adding digestate and crop residues arising from double (sequential) cropping increases soil organic carbon (SOC), compared to the reference system with no chemical fertilizer. A mass balance approach is used to quantify the SOC change by applying digestate and organic matter of crop residues from double crops. About 12% of organic matter (OM) from digestate and crop residues is converted to SOC[5]. Thus, the annual increase of SOC is 0.2–0.3 t C per ha. These values are close to those obtained from field trials using conservation agriculture practices[6]. The assessment of Ecofys[4] confirmed that soil carbon levels increased after the introduction of sequential cropping, from 2009 to 2016 by 3%.

Sequential cropping and crop rotation

In crop rotation or sequential cropping, two or more crops are grown one after the other in the same piece of land. It is advantageous when the succeeding crop belongs to a family different from that of the previous crop. The period of crop rotation may be for two to three years or longer. Sequential cropping increases annual crop yields significantly (Table1). It is widely applied (cash crop in parenthesis) in North and South America (cotton, maize), Asian countries like Indonesia (rice, Cassava), India (cotton), Nepal (mustard) and Africa (Fabaceae). Increasingly, the method enters the European agriculture.

Crop rotation is an ancient key principle of agricultural conservation because it improves the soil structure and fertility, and because it helps control weeds, pests and diseases. In addition to increased crop yields and profit, the following are the advantages of crop rotation over monoculture, the continuous growing of a single crop:

- Crop rotation suppresses the growth of weeds
- Better control of pests and diseases when rotating the crop families
- Improve the soil structure by alternating deep and shallow root plants
- Improve soil fertility by avoiding depletion of nutrients with single crop planting and increase nitrogen when including nitrogen fixing plants (legumes)
- Low iLUC risk crop production

[5] https://www.researchgate.net/publication/267717359_EFFECTS_OF_15_YEARS_SLUDGE_APPLICATION_ON_CROPLAND
[6] http://inra-dam-front-resources-cdn.brainsonic.com/ressources/afile/237958-637ec-resource-etude-reduction-des-ges-en-agriculture-synhese-90-p-.html

Sequential cropping and crop rotation

Table 1: Typical yields and fertilizer applications on a farm in the Po Valley (Source: ecofys/CIB[4])

Parameters	unit	Maize silage mono-crop	Maize silage sequential crop	triticale silage sequential crop
Fresh product yield	t/ha	62.00	53.00	46.00
Water content	%	65	67	70
Fertilizers				
Urea - 46%N	kgN/ha	80	0	0
P2O5	kgP2O5/ha	-	-	-
K2O	kgK2O/ha	-	-	-
Digestate applied	t/ha	52.5	65.3	58.6
Agrochemicals				
Pesticides	kg/ha	12.00	0.00	0.00
Herbicide	kg/ha	3.4	3.40	
Insecticide	kg/ha	1	0	

Sequential cropping has a clear advantage over catch crop. Catch Crops are cover crops which are grown after harvest of a main crop to protect – like the sequential crop -the bare soil from erosion, maintain soil moisture and reduce nutrient (nitrogen) leaching. However, while sequential crops are harvested followed immediately by the next crop (direct seeding), the catch crop is plowed in leading often to leaching of accumulated nutrients[7].

Precision farming (optimized fertilization and water management)

Traditional farming relies on managing entire fields—making decisions related to planting, harvesting, irrigating, and applying pesticides and fertilizer—based on regional conditions and historical data. Precision farming technologies, by contrast, can sense microsite specific conditions in real time and can automatically adjust treatments to meet each site's unique needs by combining sensors, robots, GPS, mapping tools and data-analytics software. As a result, precision farming can improve time management, reduce water and chemical use, and produce healthier crops and higher yields—all of which benefit farmers' bottom lines and conserve resources while reducing chemical runoff.

Apart from economic reasons, precision farming allows farmers to collect and document environmental variables, which can then be used for sustainable management activities and to promote their environmental soundness to customers.

[7] https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2389.1990.tb00040.x

Precision farming (optimized fertilization and water management)

Precision farming includes:

- adaption of crops to the local soil quality
- matching farming practices more closely to crop needs (e.g. fertilizer inputs)
- reduction of environmental risks and footprint of farming (e.g. limiting leaching of nitrogen)
- boosting competitiveness through more efficient practices (e.g. improved management of fertilizer usage and utilization of organic fertilizers).

Precision farming in the context of Biogas Done Right focuses on optimal fertilization, minimizing leaching and water saving in case irrigation is needed. Figure 3a shows a combined technology with GPS and synchronized application of digestate, shallow strip tillage and seeding. To reduce soil compaction by the weight of the digestate tank, farmers start using umbilical system (Figure 3b) connected to an underground manure grid or a tank outside the field.

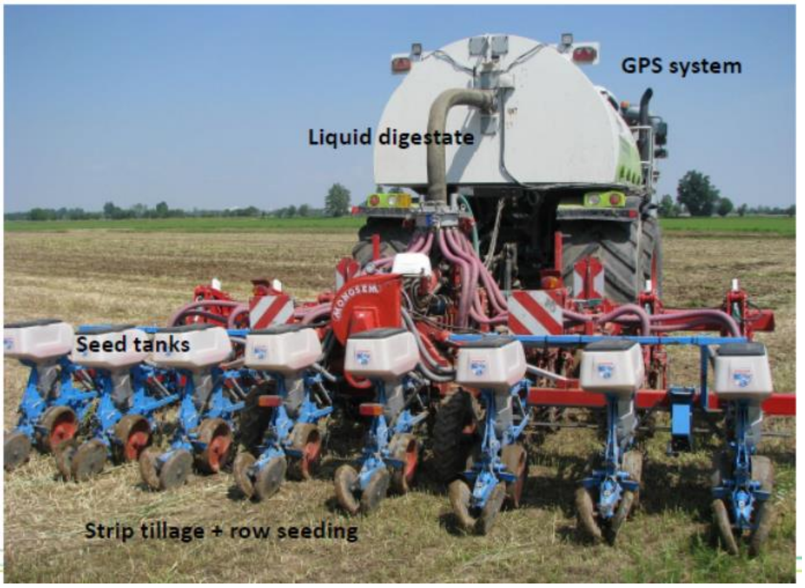

Fig. 3a
Synchronous strip tillage, seeding and liquid digestate application

Courtesy: CIB/CRPA

Fig. 3b
Digestate landspreading with an umbilical system

Courtesy: CIB/CRPA

Precision farming (optimized fertilization and water management)

This advanced technology not only preserves carbon in the soil but also water and nitrogen. In the European context, Italy is among the countries with high water consumption in agriculture. In the Mediterranean area Greece withdraws the highest share of water for irrigation with 80% followed by Spain with 72% and Italy with 60%[8]. Water saving is therefore an absolute need. After digestion the nitrogen is predominantly in the form of ammonia which binds better to the soil and is readily taken up by the growing plants. This is particularly important in case of irrigation where nitrogen leaching is enhanced. The combination of controlled irrigation and double cropping can further reduce the emission of nitrogen[9] (Fig. 4).

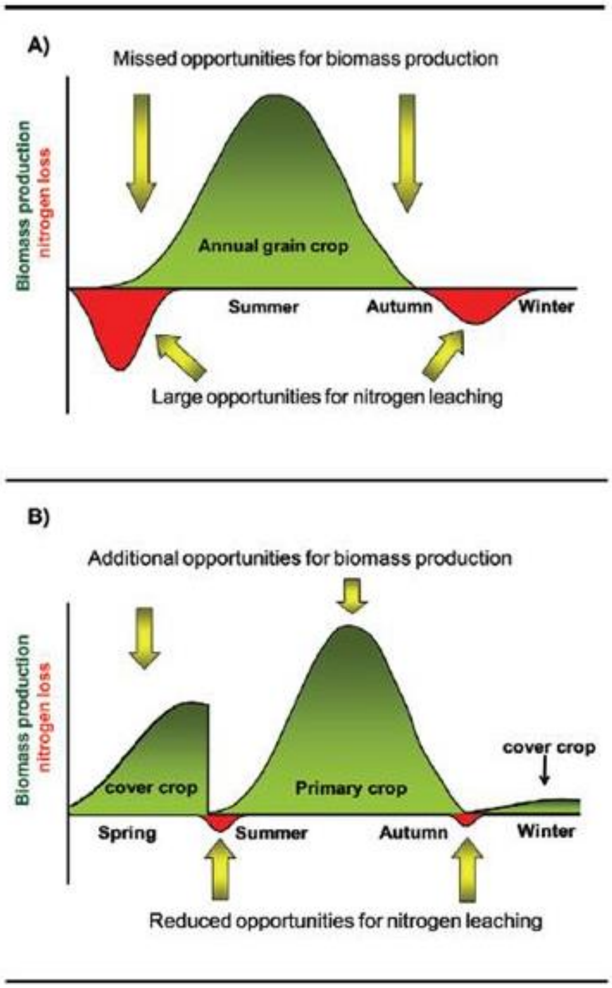

Fig. 4 Reduced opportunities of nitrogen losses and pollution of the ground water through double cropping

In the Veneto area the quality (nitrate concentration) of the aquifer was improved by 13% since biogas was introduced[10]. A further improvement was achieved with fertirrigation where up to 10% of liquid digestate is added to the irrigation water hence reducing correspondingly the water requirement. Yields increased up to 15%. Up to 100% digestate seems to be possible using a

[8] Andrea Ballocchi, (2016), L'acqua entra in gioco nell'agricultura sostenibile ed efficiente ; Biogas Informa Nr 17
[9] https://www.consorziobiogas.it/wp-content/uploads/2016/12/digestione-anaerobica-e-sequestro-di-carbonio-nel-suolo.pdf
[10] Belcaro P., Schenato F., (2015), Development of biogas and management of the nitrates in Veneto, Proc. GRASPA 2015 Workshop, Bari 15-16 June 2015

Precision farming (optimized fertilization and water management)

microfilter of 15µm allowing drip irrigation that uses the water even more efficiently[11].

Fig. 5 First trials of drip irrigation with liquid digestate were successfully tested after press and micro-filtration of the digestate. (photo from Internet)

Success stories

In northern Italy there are more than 800 biogas plants in operation. An increasing number of them switches to Biogas Done Right. Two examples are demonstrating the opportunities in a moist and temperate climate like in the Po Valley close to Cremona and in a dry area like in the south of Italy.

<u>Case study of a BDR plant in the Po Valley</u>

The farm under consideration[9] (Palazzetto farm, Cremona) is a typical example where the the farming changed from conventional agriculture to biogas with partial digestate fertilization and finally to the BDR concept. It has to be pointed out that the soil fertility of the particular farm is not the highest. The farmer manages 320ha of land with 150 heads of dairy cows. He constructed a 1 MWe biogas plant producing yearly 8.6 GWh of electricity, corresponding to 2.2 million liters of diesel equivalent. The digester was fed with animal manure and maize silage.

Before biogas production, 50ha of land were used to feed the cows (corn silage) but in addition 300 t/a of grains and 40 t/a of soy meal was bought as a feed supplement. 270 ha were available for cash crop. In 20009, when they started the digester, they fed it with manure and corn silage as a mono-crop, which lead to the situation that the whole land was needed to feed the cattle and the digester. No more cash crop could be produced. The farmer even had to buy corn silage from a neighbor corresponding to 70ha of land and also straw for the bedding. Yet, thanks to subsidies for renewable electricity, the farmer earned more money than before.

Introducing gradually from 2011 to 2012 the biogas done right concept allowed to cover both, cash crop and digester feed with a reduction of only 10ha of food and feed crop (260 ha). Fertilization is almost entirely covered by digestate, only straw for bedding still has to be purchased plus 10t/d of

[11] http://digestato100.crpa.it/nqcontent.cfm?a_id=14744

Success stories

laying hen manure from a neighbor to run the digester. On top of the financial improvement, the whole farming system became far more sustainable:

- Crop rotation is improved, from 4 crops ante biogas to 7 crops with BDR, with nitrogen fixing crops on 110 ha per year (1/3 of the farmland, 4 times more than prior to the biogas situation) including 90 ha soybean and 20 ha of alfalfa;
- Soil coverage happens almost over the whole year all over the farm and not only over the alfalfa fields (20 ha out of 320 ha ante biogas).
- The share of organic fertilization increased to ≥75%
- In the last ten years determinations of soil organic carbon showed an average annual increase of more than 10-15 per mil [12]

ARTE BDR concept in Puglia

The ARTE farm in the south east of Italy (not too far from Bari) manages 230 ha of own land and 300 ha in rent. Apart after the introduction of the BDR concept in 2010 the cultivation was subsequently turned into organic farming. The cash crop includes all kind of food like barley, cereals, spelt, peas, lentils, flex, hemp, grapes, olives and almonds (Fig. 6). Over the years they invested into precision farming with simultaneous shallow plowing, fertilization and seeding. This allowed to reduce the fuel consumption from 80 liters per ha to 15 liters per ha. Shallow plowing (top 5 centimeters) brought the additional advantage that the seeds grow in a desalinated environment because the rain washes out the chlorine of the top soil. The ground is rich in sodium chlorine because of the earlier salt drying in the area (power point presentation of M. Borelli, Agricola ARTE, 2017).

Double cropping is done with sequences of barley and beans, or pigeon beans followed by hemp, or Triticale followed by sunflowers. The first culture is never irrigated while the summer culture needs some water.

Figure 6. Double cropping of pigeon beans (favino) followed by hemp

The digester with an installed power of 625 kW_{el} is fed with energy crop from sequential cropping of 250 ha (triticale, barley and beans) that covers 50% of the biogas need. The rest is covered by 25% from sub-products of the agricultural production like leaves and pomace from the olives, and other agricultural residues from cereals and pasta production and up to 35% of dung and manure from

[12] Mantovi-et-al. "Enhance soil organic carbon stocks by means of the Biogasdoneright system" . Oral paper "Soil organic matter management in agriculture Assessing the potential of the 4per1000 initiative." Braunschweig 2018. Book of Abstract

Success stories

partnering farms. The electricity covers the needs of the whole farm including the production of olive oil and pasta. The heat (900 kW_{th}) is used for heating and hot water production for the dwellings and the production processes. In addition, part of the digestate is dried from 5% dry matter to 85% with hot air to fertilize the more distant farms. Organic farming requires 100% organic fertilizer. The systematic application of digestate together with combined plowing, fertilization and seeding brought an increase of the soil organic carbon from 1.18g/100g in 2008 to 1.27g/100g in 2015 (+7.6%).

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