BIOGASDONERIGHT®

ANAEROBIC DIGESTION AND SOIL CARBON SEQUESTRATION

A SUSTAINABLE, LOW COST, RELIABLE AND WIN WIN BECCS SOLUTION

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1 Bioenergy and carbon capture sequestration system

Preface by Bruce Dale[2]

Our world is changing. Since the beginning of the Industrial Revolution, over two centuries ago, humankind has grown greatly in energy consumption, wealth and population. These outcomes are all strongly linked. With abundant energy, humans can produce much more, including more food, become richer, reduce infant mortality, control more diseases, live longer and become better educated. All of these are good outcomes enabled by inexpensive, abundant fossil fuels.

However, abundant fossil energy also encouraged humankind to ignore or circumvent natural processes, including maintaining soil fertility. Fertilizers based on cheap fossil fuels and huge fossil energy inputs to plant, till and harvest crops could substitute for loss of fertility. With each hectare yielding more, we could, for a while, ignore erosion, desertification and salinization of lands, all destructive practices enabled by cheap, abundant fossil energy. Overhanging all of these more localized destructive outcomes are the largely destructive impacts of global climate change driven primarily by fossil energy use.

We are now in a time of transition. Oil, the queen of the fossil energy resources, is increasingly expensive and environmentally destructive to extract and use. The peak of inexpensive, or conventional, oil production passed in 2005. We have now entered the age in which oil consumption is largely supply limited, rather than demand limited. Current low oil price levels are not an exception to this statement. Economic growth requires increased energy consumption, including more oil consumption. However, high oil prices over the past few years have reduced economic growth, leading to lower demand growth for oil and contributing to even more global economic slowdown and thus reduced oil prices. Current low oil prices will discourage investment needed to bring new oil resources on line, leading to even more restricted future oil supplies and much higher oil prices, reducing economic activity still more. If we pursue our present path, this downward spiral will continue.

Is there a way out of this and many other "vicious circles" currently afflicting humankind? Yes, there is. Our way out begins with realizing that constantly growing energy use and a constantly growing economy are physically impossible on a large but finite planet. We must realize that our present economy is based primarily on destruction of the planet and frequently on the exploitation of humankind. We must change the way we think about the planet and about people.

Of all the things that are difficult to change, changing our minds is the most difficult thing of all. But change we must. We must change the question from "how can we consume more this year?" to "how much do we need?" We must change the question from "how can we do less harm to the earth with our technologies?" to "how can we meet our needs while making large environmental improvements?" In a word, it is time for humankind to grow up and get smart.

Humans need about 2-4 kilowatts of power per capita to achieve good levels of education, health and economic activity. We need about 2000 kcal of food energy and about 50 grams of protein per capita per day as macronutrients, plus a host of micronutrients. We need clean air and clean water. We need a stable, moderate climate. These are our basic physical needs.

Total world energy use is about 16 terawatts, or about 2 kilowatts for every person on the planet. But energy use is not evenly distributed. Overall, many more people live far below the 2-4 kW/capita threshold than live above it. Uneven power consumption promotes uneven wealth distribution and resulting hunger. Also, about 85% of current power consumption is based on fossil energy, contributing significantly to growing atmospheric carbon dioxide levels. Modern agriculture is based on large fossil energy inputs to produce a very limited range of outputs to serve a few markets. It is thus both inherently risky and unsustainable.

Thus we need to produce much more energy, but not from fossil carbon resources. We must make energy production much more widespread and "democratic". We must increase soil fertility and overall agricultural production without increasing agricultural inputs. We must produce much more food to provide for a growing human population while at the same time diversifying markets for agricultural products and attracting more investment in agriculture. We must take very large amounts of atmospheric carbon dioxide and sequester it long term. To say the least, this is a very challenging set of nested, interlinked challenges.

The Biogasdoneright® platform technologies meet all these needs and address all of these challenges. This article explains why and how. I deeply appreciate the work done by Italian biogas producers to pioneer these simple, low-cost technologies that link sustainable agriculture with a sustainable planet. I am greatly honored that they have chosen to name their project after work done by me and my colleagues at Michigan State University to produce sustainable liquid fuels from plant biomass. But now, read for yourself what these visionaries are accomplishing and how they hope to diffuse their technologies world-wide.

2 Bruce Dale, Michigan State University Distinguished Professor; MSU AgBioResearch

FOREWORD

A recent Google engineers article stirred the debate in the renewable energy sector: "*Suppose for a moment that it had achieved the most extraordinary success possible, and that we had found cheap renewable energy technologies that could gradually replace all the world's coal plants—a situation roughly equivalent to the energy innovation study's best-case scenario. Even if that dream had come to pass, it still wouldn't have solved climate change. This realization was frankly shocking: not only had RE<C failed to reach its goal of creating energy cheaper than coal,* ***but that goal had not been ambitious enough to reverse climate change.***" [3]
This article proposes an inexpensive, widely-proven and widely-applicable means of reversing climate change using bioenergy and associated carbon capture and storage. We propose a systemic approach to agriculture, where we obtain food and feed and energy/biomaterials from the same hectare of land already cultivated or set aside. We achieve this target via a combination of already existing and new farming techniques and while we photosynthesize more carbon in the crops we sequestrate CO_2 from the atmosphere and we store it in the soil, making it richer in organic matter and thus more fertile.

We call these techniques biogasdoneright® since the whole farm activity is designed around the anaerobic digester (AD).

Bioenergy is a controversial issue, questioned from many Scientists and Policymakers. Many among them believe that there is no way to produce organic carbon for bioenergy without direct or indirect impact on food and feed carbon availability, or without environmental services limitations.

That could be even true if we consider current agricultural techniques based on fossil fertilizers and fuels, or if we imagine to clear virgin forest or grassland to get more agricultural land to produce row crops.

This does not mean that we have to remove bioenergy from the renewable energy pool. Agriculture and afforestation are key players in the carbon cycle; biosphere and soil are the biggest carbon reservoir today available where to sequester and store the carbon that since the industrial revolution we added to the atmosphere.

All the most plausible scenarios where the CO_2 concentration will remain under 450 ppm rely on some forms of CCS technologies (either BECCS or conventional CCS). "*A pulse of CO_2 injected into the air decays by half in about 25 years as CO_2 is taken up by the ocean, biosphere and soil,* ***but nearly one-fifth is still in the atmosphere after 500 years****. Eventually, over hundreds of millennia, weathering of rocks will deposit all of this initial CO_2 pulse on the ocean floor as carbonate sediments*"[4].

There is then an urgent need to mitigate as much as possible the CO_2 emission from the conventional agriculture, increase the NPP via additional carbon and allocate as much as possible the additional carbon to the soils, thus improving their fertility and make the farmland more resilient to the current effects of climate change, that farmers worldwide are beginning to perceive.

In order to produce additional carbon sustainably, agriculture to look back to its past, where it was able to produce food, feed and energy or biomaterials from the same field, freeing the farms from the "addiction" of conventional farming to fossil fertilizers, recycling the additional carbon and the nutrients in the soil and thus increasing their fertility.

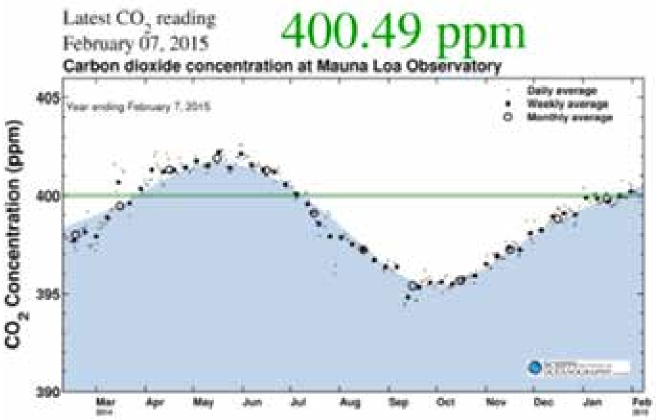
"*Fossil fuels account for ~80% of the CO_2 increase from preindustrial time, with land use/deforestation accounting for 20%. Net deforestation to date is estimated to be 100 GtC (gigatons of carbon) with ±50% uncertainty . Complete restoration of deforested areas is unrealistic, yet 100 GtC carbon drawdown is conceivable because:*
1. the human-enhanced atmospheric CO_2 level increases carbon uptake by some vegetation and soils,
2. improved agricultural practices can convert agriculture from a CO_2 source into a CO_2 sink
3. biomass-burning power plants with CO_2 capture and storage can contribute to CO_2 drawdown"[5].
A carbon negative agriculture able to produce for more markets food, feed anergy and biomasterials is maybe the best answer to the dilemma highlighted by the google engineers.

3 http://spectrum.ieee.org/energy/renewables/what-it-would-really-take-to-reverse-climate-change
4 "Assessing "Dangerous Climate Change: Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature"
5 Hansen James, 2013 op. cit.

Bioenergy and carbon capture & Sequestration

Bioenergy is the only renewable source that could act, at the scale that we need on the carbon cycle, as the Keeling curve "swing" every summer is showing us.

KEELING CURVE 2014-2015



The IPCC[6] recently once again pushed starkly forward the thesis that in order to prevent abrupt climate change scenarios the mere production of carbon neutral electrons will not be sufficient, and that technologies able to sequestrate CO2 directly from the atmosphere will be needed. "Mitigation scenarios reaching about 450 ppm CO2eq in 2100 typically involve temporary overshoot of atmospheric concentrations, as do many scenarios reaching about 500 ppm to about 550 ppm CO2eq in 2100"[7] .

Depending on the level of the overshoot, overshoot scenarios typically rely on the availability and widespread deployment of **BECCS**[8] and Afforestation in the second half of the century.

The availability and scale of these and other Carbon Dioxide Removal (CDR) technologies and methods are uncertain and CDR technologies and methods are, to varying degrees, associated with challenges, risks and often with low Technology Readiness Level (TRL), not to mention the social acceptance (conventional CCS technology is at the moment strongly opposed by the public opinion[9]).

In relation to BECCS, the IPCC underlines that "T*here is uncertainty about the potential for large-scale deployment of BECCS*" . Moreover[10] "*Combining bioenergy with CCS (BECCS) offers the prospect of energy supply with large-scale net negative emissions which plays an important role in many low-stabilization scenarios, while it entails challenges and risks (limited evidence, medium agreement)*. ***These challenges and risks include those associated with the upstream large-scale provision of the biomass that is used in the CCS facility as well as those associated with the CCS technology itself.***".

According to IPCC then, BECCS systems are necessary albeit they must prove that:

1. They are able to increase the amount of renewable carbon that is sequestered, without lowering the carbon that is needed for Food & Feed, material and industrial applications and for environmental functions such as increase or maintenance of biodiversity or organic content of the soils;
2. the production of such renewable carbon will not worsen the CO2 emission of the primary sector, something that will occur when using conventional agricultural techniques;
3. they are able to sequester the renewable carbon in sinks that are stable, easy accessible, safe and equally distributed worldwide;
4. the combined costs of capture, transport and sequestration of CO2 will be the lowest possible;
5. the BECCS could be socially accepted when they will bring positive externalities toward the challenges that lay ahead of humans beside climate change (raising world population, increased energy demand from developing countries, soils desertification, biodiversity protection, climate change induced migrations[11]).

6 http://mitigation2014.org/report/summary-for-policy-makers
7 CLIMATE CHANGE 2014 Synthesis Report http://www.ipcc.ch/pdf/special-reports/srren/Chapter%202%20Bioenergy.pdf
8 Bioenergy and carbon capture and sequestration
9 https://sites.utexas.edu/mecc/2014/05/09/ccs-in-poland-and-germany/; Public acceptance of CCS system elements: A conjoint measurement; Lasse Wallquist, , Selma L'Orange Seigo, Vivianne H.M. Visschers, Michael Siegrist; Int. J. of Greenhouse Gas Control;, January 2012, Pages 77–83
10 Op. cit. pag. 21
11 The planet is facing challenges that have never been seen during its history. Global warming is only one of the facets of a complex problem that links together climate change, increasing world population, water shortages, soil degradation, desertification and climate change induced migrations.
12 (omissis)

BIOGASDONERIGHT®

We use the term "biogasdoneright®"[13] to describe a technological platform that combines Anaerobic Digestion (AD) technologies and other Industrial and Agricultural practices that when applied synergistically are able to:

- produce additional carbon both in already farmed land and in land that suffer desertification or lowered productivity, especially in dry lands,
- simultaneously increase the World Net Primary Production (NPP) of farmland and lower the negative externalities associated with modern conventional agricultural practices;
- continuous increase (until an equilibrium is reached) of the organic content of soils sequestering carbon at the required scale (> 1 Gton C per year) through a steady management of new organic matter input to the soils via green mulching and AD digestate spreading, thus also confirming and extending previous results obtained by organic farming to ameliorate soils health;
- realize this at very low cost, since the CO_2 capture, transport and distribution costs could be paid off by services (the increase of soil fertility, soil water retention, soil biodiversity, etc) and sale of products (food/feed, energy, biobased materials);
- contribute at the same time to an ecological agricultural intensification, to a capillary adoption of organic fertilization decoupled from the livestock industry growth, increasing the resilience of ranchers and farmers to ongoing climate change effects, improving the economics of farming, largely freeing farms from fossil fertilizers and fuels and thus transforming BECCS from a cost to an economically profitable opportunity scalable worldwide, able to attract more investment toward primary sector as we also need at least to increase food production.

Breaking the spell: producing energy & sequestering carbon is possible without lowering food & feed production

In the light of the other major challenges before us (increasing world population and decreasing per capita farmland) we cannot accept the idea of sequestering carbon by reducing food and feed carbon available on the markets.
More specifically, we are convinced that growing a monoculture just for feeding the AD digesters or any other bioenergy system, or using a non-food perennial crop on farmland that already cultivated, are bridge solutions that can be applied only in times like today, where prices for agricultural commodities are low and the additional demand from biofuels (especially corn ethanol) keeps the price at a level that is still possible to produce[14] rather than leave the farmland to set aside, thus preventing the farmers for going bankrupt.

Even without ethical considerations[15], we recognize that market diversification for farm outputs is needed to attract investments in the primary sector, thus contributing to the increased food production needed by the world increasing population.

But the use of plant biomass already produced for the Food & Feed market **is not able to remove substantial amount of carbon from the atmosphere**, at least not at the scale required to stop and reverse climate change.
In general, the use of agricultural by-products or livestock manure moves carbon from one biome to another one, and does not increase the carbon removed from the atmosphere, but mitigates emissions from misuse of these organic matrices (industrial by products and manure).

What is needed then to develop effective techniques of carbon sequestration is the production of additional carbon, meaning carbon that today is not produced for food, feed or any other application. This additional carbon must be produced through an ecological agriculture intensification of the farmland, in a diffused and broad range process of "biosphere carbonization"[16], that relies on an increase of the NPP of cultivated and degraded, marginal and under desertification lands, while avoiding the emissions related to current agricultural systems.
Regarding additional carbon, anaerobic digestion is able to contribute more than any other bioenergy source due to its peculiar characteristics:

- AD can efficiently convert the carbon (from 70 to 85% of organic carbon) into biogas even at small scale (> 500.000 liter/year of diesel equivalent) and with technologies that are easily deployable even in developing countries by using biotechnology that is well known, cost and patent free.
- It is a multi-feedstock technology able to work in many different agricultural and ecological conditions

13 We have been inspired by the researchers Lee Lynd, Bruce Dale , etc. that we would like to thank publicly. In particular the "biofuels done right "concept was for the first time elaborated by Bruce Dale and Others "Biofuels Done Right: Land Efficient Animal Feeds Enable Large Environmental and Energy Benefits" Environ. Sci. Technol. 44, 8385-8389, 2010

14 http://www.fao .org/about/who-we-are/director-gen/faodg-statements/detail/en/c/275129/ Global Forum for Food and Agriculture, 2015 FAO Working Meeting "Addressing Food Security Challenges under Increasing Demand for Land, Soil and Energy" Opening statement by FAO Director-General José Graziano Da Silva 16 January 2015, Berlin, Germany

15 Unfortunately, we are not able to influence the reasons why more than one billion person on the planet still suffer from malnutrition. The causes are not rooted in the lack of food production, but in the socioeconomic performances of the countries where do they live.

16 "Recarbonization of the Biosphere. Ecosystems and the Global Carbon Cycle" Lal, R., Lorenz, K., Hüttl, R.F., Schneider, B.U., von Braun, J. (Eds.)

and also in different climatic zones, from Norway to Morocco via Europe mainland.
- It is able via digestate to bring back any farmer to organic fertilization, even in absent of livestock manure or slurry[17].

In our definition, biogasdoneright® platform technologies is a technological platform around which a farmer can redesign its nutrient cycles and land use in order to:
- increase the primary production of the farm, allocating the production of additional carbon to the anaerobic digestion, augmenting the feed to the digester by adding livestock effluents, organic urban and industrial wastes, and in this way recovering in an effective and sustainable way organic carbon and nutrients from wastes often responsible of air and water pollution;
- realize the above mentioned production of additional carbon
  - Without lowering (often increasing...) the food and feed production prior the biogas plant construction.
  - Lowering or completely avoiding the need for fossil fertilizers and fuels,
  - Increasing the organic matter of the soil, improving crops rotation and annual vegetation land coverage, increasing the use of nitrogen fixing plants,
  - Decoupling organic fertilization inputs from the need for livestock industry growth, an industry that is responsible for a large fraction of GHGs emissions of current agriculture.

In other words, the careful application of the biogasdoneright® platform technologies principles to the farm revolutionizes agricultural practices, by transforming current, unsustainable conventional agriculture systems into sustainable, lower cost and carbon-sequestering systems.

The land efficiency of a biogas plant: a case study in a temperate climate (The Po river plain)

These concepts can be illustrated by a case study of a farm converted from conventional agriculture, then to biogas and later to the biogasdoneright® platform technologies.

First, some relevant data about this farm in NE Italy are reported, in order to bring in firsthand experience and numbers regarding the land efficiency[18] and soil carbon organic input. The farm is located in the Po river plain, in a moist and temperate climate, and includes 320 hectares and a dairy stable with 150 cows.

The farm constructed a 1 MWe biogas plant producing yearly 8,5 GWh of electricity, corresponding to 2.2 million liters of diesel equivalent biogas capacity.
In order to feed the biogas plant, the farmer faces two diet options :

A. Monoculture crops [19]:
- using biomass produced by only annual crops, energy crops are substituted for food & feed previously produced
- a typical case is the use of corn and the biogas plant would need about 42 tons fresh matter corn silage per day in addition to 20 ton of bovine slurry and manure .

B. Biogasdoneright® platform technologies biomass, thus relying on the concept of ecological agriculture intensification and organic waste incremental use, i.e.
- Cover crops (second harvest) before or after food & feed traditional crops[20], thus keeping the hectares dedicated to food & feed nearly at the same level as before the biogas plant construction, and producing double crops in the period of the year when the land was set aside,
- Livestock effluents, in our case either originating at the farm or bought from neighboring farms (10 ton/day of eggs poultry manure).
- Nitrogen fixing plants, in rotation with other cereals for the market
- Perennials in set-aside lands or lands undergoing desertification, especially where farming has been abandoned or there is no agriculture output is not present
- Agricultural byproducts, provided that the soil carbon fertility is at least maintained.
- Organic wastes.

Here are two examples of feeding recipes (expressed as ton of dry matter per day) for this biogas plant in Italy[21]. The biomass materials are classified in three different ca-

17 The carbon of the digestate represents the most recalcitrant part of the biomass (undigested cellulose and lignin, rich in prehumic substances). This carbon will contribute to stable carbon stored in soils, thus the use of livestock manure does not reduce the addition of prehumic substances to the soils.
18 The land efficiency of bioenergy can be defined as the quantity of primary energy that can be obtained by 1 ha of agriculture soil used in substitution of first harvest crops previously used for food & feed applications (First crop land requirement FCLR).
To deepen the land efficiency concept see the annexed presentation of Stefano Bozzetto at the Amsterdam EBA congress of 2014 "Biogas and sustainable farming: Could we achieve a sustainable farming w/out biogas ? " and also the text of Lee Lynd and other authors "energy myth three – high land requirements and an unfavorable energy balance preclude biomass ethanol from playing a large role in providing energy services" B.K. Sovacool and M.A. Brown (eds.), Energy and American Society – Thirteen Myths, 75–101, 2007
19 In other words biomass coming from only one crop cultivated during the year, in this case corn silage.
20 In this case triticale silage, mix of triticale and grasses silage, corn silage, sorghum silage

tegories depending on the carbon they contain and are as follows:

1. Carbon taken of food and feed production
2. Carbon taken from other bioma
3. Additional carbon or carbon that would have not been produced with conventional agriculture and that is produced for feeding the AD. With no AD this additional carbon would not have been produced cause lack of market demand.

ton dry matter /day	BIOGAS from mono cultures			BIOGASDONERIGHT		
	Additional C	C from others bioma	C substitutional of food and feed	Additional C	C from others bioma	C substitutional of food and feed
Wheat Silage				1,2		
Wheat grain				-		
Mix winter cereal/nitrogen fixing crops				1,7		
Triticale Silage				3,9		
Partial winter crops	-	-	-	6,9	-	-
Corn silage for stable				-		
Corn silage for digesters			14,3	6,1		
Corn grain				-		
Sorghum grain				-		
Soghum silage						0,4
Partial summer crops	-	-	14,3	6,1	-	0,4
Chicken manure		-			3,1	
Bovine manure		1,6			1,9	
Bovine slurries		0,4			0,6	
Partial livestock	-	2,0	-	-	5,6	-
OVERALL TON DRY MATTER DAY	-	2,0	14,3	13,0	5,6	0,4
			16,2			19,0

In this case study, cover crops produced after/before cash crops, play a predominant role in feeding the biogas plant behind livestock effluents[22].

For the second harvest crops following wheat production the choice was corn silage. In the FAO 300/500 class this crop, combined with no tillage agriculture, digestate fertilization and further fertirrigation, reaches an acceptable yield per hectare and full maturity (starch content > 25%, dry matter content around 30-32%) when harvested in October without compromising the soil tillage for the following crops[23].

This strategy allowed the farm to produce energy at about 450 Nmc/h of raw biogas, equivalent to 2.100.000 Nm3 of methane per year, narrowing the land area devoted to food and feed by only 10 hectares out of 320 hectares. Often the double cropping[24] strategy has as a side effect[25] reducing the photo/thermo period for the cash crop that follows, but at this farm all the harvests showed a 10-15% yield increase, due to:

- Improved soil fertility after few years of organic fertilization
- Adoption of digestate distribution systems (umbilical distribution) that avoid soil compaction, for example via digestate burying in the soil
- Adoption of watering techniques (drip irrigation, pivot irrigation) that are more efficient and water saving
- Distribution of nutrients via the irrigation system, even of chemical fertilizers such as ammonium sulfate, that can be produced from renewable resources (ammonium sulfate from the digestate)
- Adoption of no tillage agriculture for seeding, thus keeping the moisture of soils and shorten the time between first and second harvest.

In the supplementary material some innovative practices and techniques that have been adopted and developed by the Italian biogas farmers are displayed. This fact shows that the biogasdoneright® platform technologies fosters innovation in farming without specific regulations.

Moreover, biogas demand triggers improvements in crop rotation, with higher biodiversity as indicated by the graph here below, where the crops of the three different scenarios are represented:

- ante biogas plant
- biogas with monoculture of corn silage
- biogasdoneright® platform technologies diet

21 1 MWe plant, nearly 450 Nmc/hour of raw biogas, 8.600 MWh el/year. See the annex for a detailed explanation.

22 In the current market situation not all the harvested crops are sold to the market, but a part has been used for biogas production due to the extremely low market prices. When the prices will go back to normal level then the farm will be able to invest on the machinery and infrastructure needed for the fertirrigation and for the conservative agriculture.
The project diet of the biogas plant then is still in progress. This means that there is no technological limit to the biogasdoneright diet application, but just that the current market situation makes difficult to invest further at the moment.

23 In the second harvest becomes irrelevant if the biomass is food or non food, what is important is the ability to produce additional carbon in a sustainable way. Maize in second harvest is thus the most efficient solution, and crops with dual purpose food & energy is a good choice since if needed the maize can be sold on the food market rather then used for bioenergy.

24 In this respect the following text is a must to read "Second Harvest: Bioenergy from Cover Crop Biomass" NRDC 2011 http://www.nrdc.org/energy/files/covercrop_ip.pdf

25 Potential drawbacks of the second harvest are well known and include reduced yield due to lower water input and shortened photoperiod. Moreover, the combined effect of designing the second harvest as hard dough silage for the biogas and the increased yield due to the digestate renders the yield of cash crops significantly higher than in the years ante biogas.

Compared to the ante biogas plant situation:

- Crop rotation (including biodiversity) is improved, from 4 crops ante biogas to 7 crop, with nitrogen fixing crops of 110 ha per year (1/3 of the farmland, 4 times more than prior to 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 over 320 ha ante biogas, now 320 ha over 320 ha all year around!), by improving photosynthetic land efficiency and reducing leaching and run off phenomena;
- The straw needed for the stable is now not purchased off the farm as in the case of only corn silage digester diet, the farm is again in the position to self-produce straw for its own needs and at the same time increases the production of agricultural residues.
- The fertilization needs are almost entirely covered by the nutrient cycling via digestate.

The additional carbon production is clearly explained by the following chart that shows us the net land coverage increase and the photosynthetic efficiency improvement.

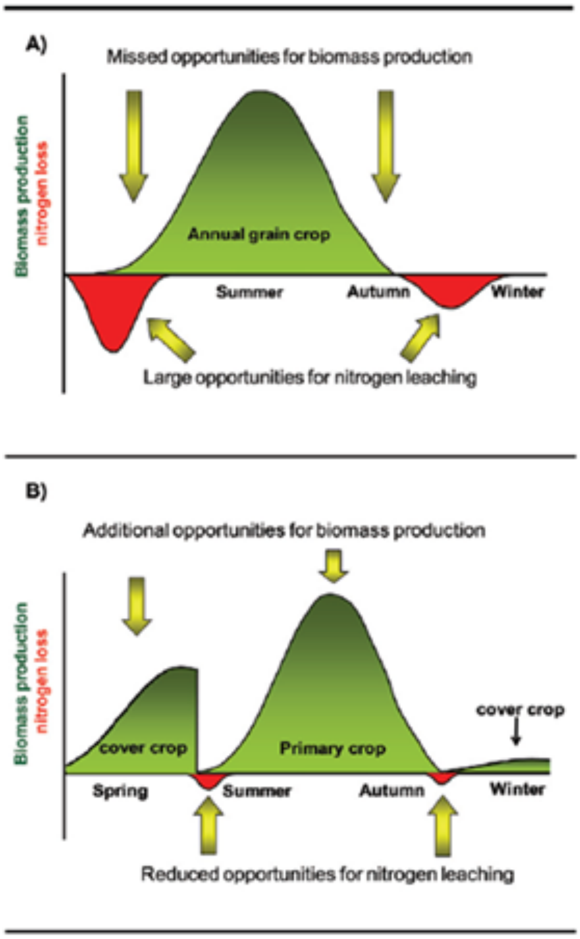
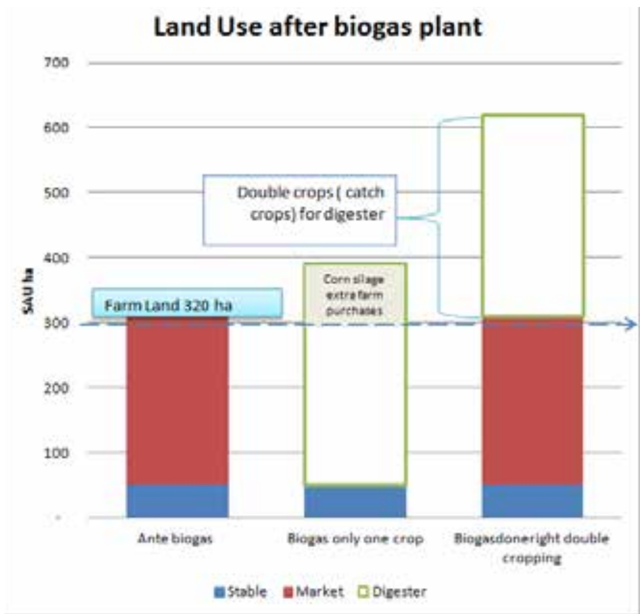


Fig. I. Hypothesized representation of the seasonal dynamics of dry matter production and NO_3–N leaching (A) in an annual grain cropping system and (B) in a bioenergy double-cropping system.



26 Silage, due to its high water content, cannot be economically transported over long distances.

Summarizing:

- In the "corn silage" monoculture option, the carbon needed for the AD can be produced only when the farm does not produce any more carbon for food & feed markets. To make matters even worst, the farm needed to also buy 70 ha of corn silage off of the farm, and since there is also no more winter cereal production, the farm must purchase straw bales for the stable.
- In the use of soil with the Biogasdoneright® platform technologies principles, the largest part of the biomass for the AD originate from the production of additional carbon, meaning that it is carbon that would have not being produced if the AD was not in place; but is carbon produced by ecological agricultural intensification that allows:
- Grasses, cereals and nitrogen fixing crops to be stored as silage[26] thereby saving the days till grain maturation enabling double cropping land use strategy;
- Reduced or eliminated fossil fertilizer inputs since the digestate and its nutrients allow the widespread use of organic fertilization;
- Increased nutritional value of the digestate and improved biology of the digesters via livestock effluents, even effluents collected from neighboring farms, thus reducing the environmental impact of these effluents and improving also the storage, treatment and distribution of the organic fertilizers;
- Investments in the hardware needed for fertirrigation, for digestate distribution, for the practices of conservative agriculture. These increased investments are justified because the farm minimizes business risks due volatile food prices trend by market diversification and the farm's improved cash flow.

Biogasdoneright® platform technologies land use: the increase of the organic matter content in agricultural soils

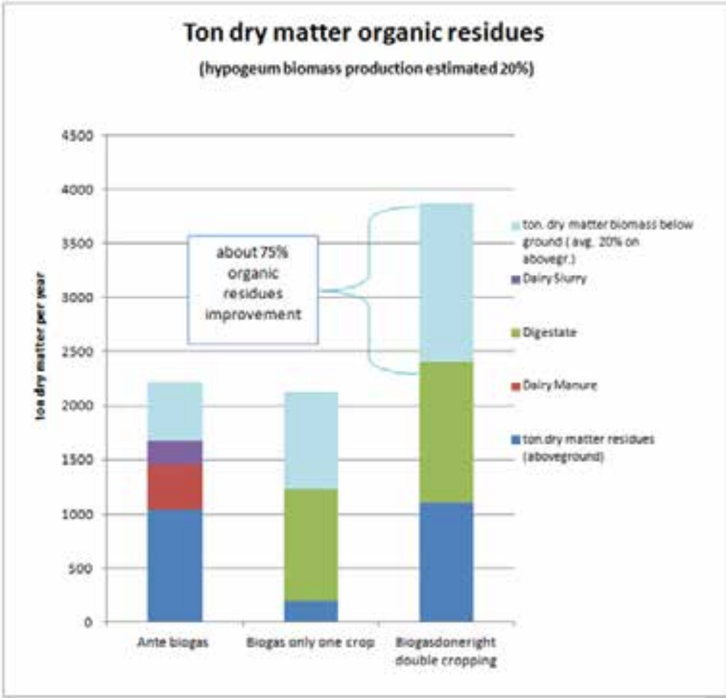
The farm described in this example is located in the Po River Valley, and is just one example of the Italian biogasdoneright® concept and is not even the most advanced in terms of productivity and land use efficiency.

The soil texture at this farm is claim rich soil, sometimes loamy.
Usually supplemental irrigation is needed in order to achieve high yields with summer crops. The farm recently started to monitor soil fertility via soil mapping. These analysis showed a decrease in soil fertility with increasing distance from the stable; this decrease can be explained to the limited organic fertilization that was achieved in the ante biogas situation, where the manure was enough to cover the needs only of one third of the farmland[27].

The construction of the biogas plant and the application of the biogasdoneright® principles not only produce the above mentioned beneficial effects, but also increase the macro and microelements in the soil via the elements in the digestate[28]. At the same time application of these principles increase significantly the quantity of carbon that is added to the soils and which originates from:

- Aerial biomass residues
- Hypogeal biomass, increased by the higher yields and by cover crops addition
- Livestock effluents after their use in the AD
- The digestate

Here below are reported the quantities of organic matter (expressed as tons of dry matter per year) administered to the farm soil for this case study.



These chart clearly show the potential extra amount of organic matter that could be converted into stable organic matter (humus) via the humification potential of every type of organic matter added to the soil.
We know that the values in the graph are only representative numbers but it is clear how the three different scenarios evolve:

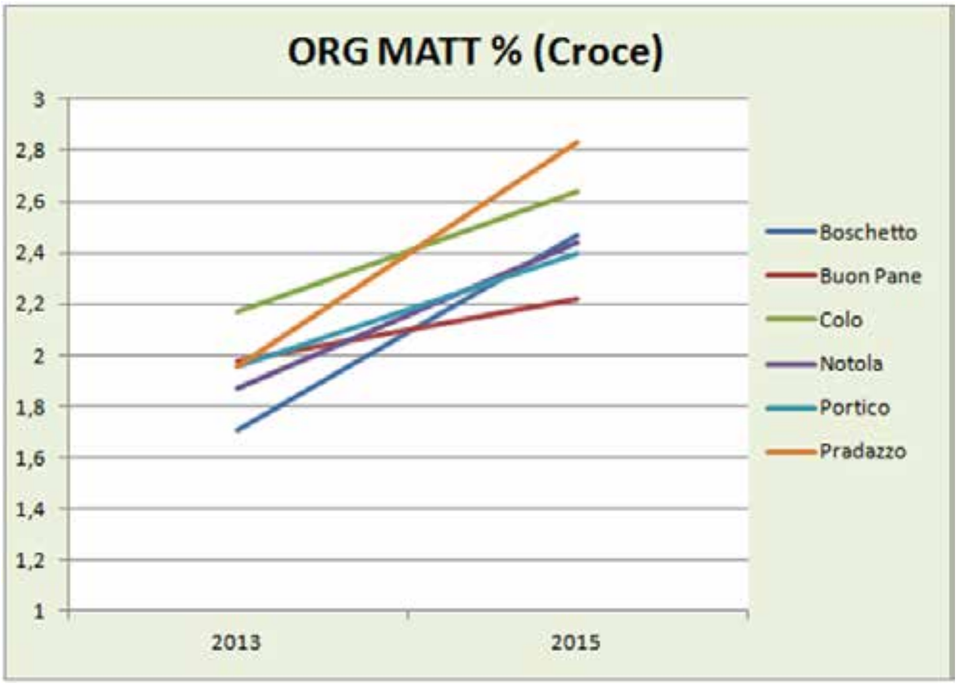
1. In respect to the ante biogas scenario, substitution of wheat/corn grain and soy bean production with corn si-

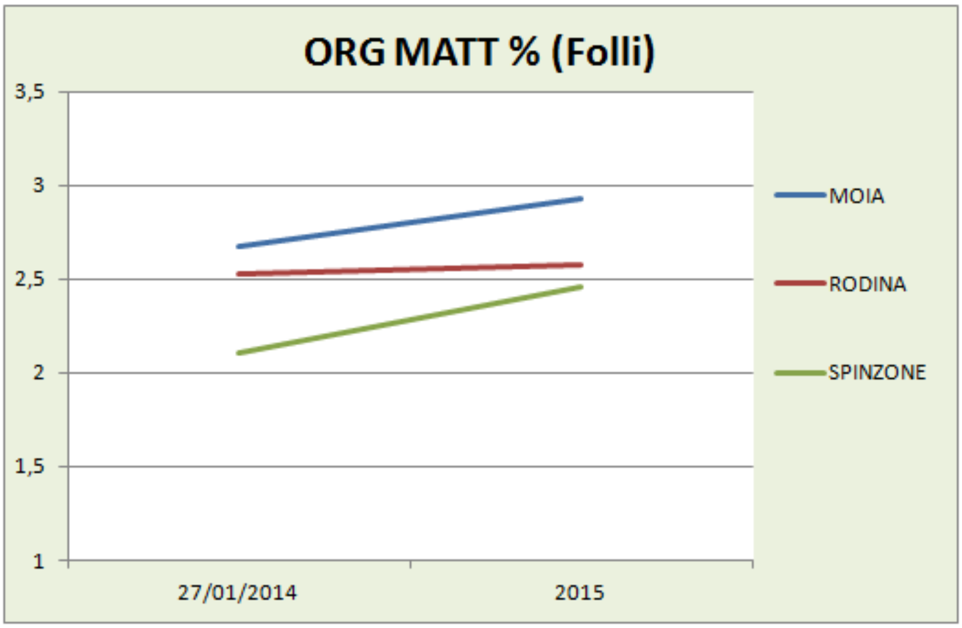
27 It is very often forgotten that organic farming diffusion is limited by the concentration and the availability of livestock in the area. For example, in the same district where the farm here described there are 500 cows and 7.500 ha of farmland: these numbers tell us that is not feasible to convert all of the farmland of the district into organic farming.
28 "La méthanisation rurale, outil des transitions énergétique et agroécologique" Christian COUTURIER SOLAGRO 2014

lage mono-cropping (biogas only one crop) causes less stover to return to the soil. The farm must buy wheat straw from neighboring farms and the C-soil balance is on deficit (about -5% less carbon inputs). The production of biogas from monoculture in this case not only deprives the carbon for food and feed markets, but even reduces the amount of carbon to the agricultural soil in respect to the ante biogas scenario.

2. Conversely, in the biogasdoneright® crop rotation case, the biogas is produced not relying on the biomass for the food and feed market; the yearly organic matter administered to the soils is increased by 75%, organic fertilization on all the farmland is enabled with increased soil organic matter, where it was often below 1%, with beneficial effects on the increase of soil fertility and NPP. **The combined effect of switching to organic fertilization and the ecological intensification of crop rotations prove themselves to be a real game changer, contributing to redesigned nutrients cycles and crop rotations to achieve an increased soil organic matter content, as has been demonstrated in many specific cases**[29].

MEASURED ORGANIC MATTER INCREASE IN THE SOIL OF FARMS APPLYING THE BIOGASDONERIGHT® IN THE PO RIVER VALLEY.





29 Organic matter trends in a Po valley farm after two years of digestate administration, obtained from "Optimizing the digestate use: the right approach for the valorization of it" of Paolo Brachitta, Pioneer Italy, presented at Biogas Italy 2015

Biogasdoneright®: a meaningful tool for an ecological agricultural intensification

The biogasdoneright® at the farm in Po River plain, due to its ability to integrate with the traditional farming already existing before the biogas plant, improved the economics of the farm and made it independent of fossil fertilizers input[30]. Managing the digestate from biogas production back in the fields shows to be an effective tool in recycling nutrients and double cropping land coverage help to improve soil fertility, and reduce nutrient and carbon leakage and erosion.

In other words the benefits brought by the biogas plant allow:

- Mitigation of emissions linked to the modern farming and livestock management
- Enhanced organic content of the soil that plunged in the past to as little as 1,2% of OM, since the livestock manure was not sufficient to cover the entire farmland
- Decoupled organic fertilization from the need to increase of the farm's livestock levels, especially in a moment where milk and meat prices are very low.
- Improved farm economics, strengthening and making more regular cash flows, thus allowing the farm to invest further in improving its agricultural practices

In the attached documents there are pictures and descriptions of innovative farming practices that have been adopted by the Italian biogas producers[31] due to their effectiveness and flexibility of use.
The adoption of minimum soil work, strip tillage, no labour seeding, drip irrigation, digestate valorization when is needed by interim storage, etc., together improve the NUE and WUE[32] of the farm significantly.
As result the farm can realize additional carbon production that is almost twice that obtained before the construction of the biogas plant, with a land efficiency measured as land needed for the first harvest of 5 Ha every 1 million liters of diesel equivalent, thus in this case 2.150 MWh th per hectar of land subtracted to food & fed production[33].
As a comparison 1 hectare of soy can produce 15 MWh th/ha of biodiesel, while a palm oil hectare produce circa 60 MWh th per year.

With the biogasdoneright® principles, the sustainability of the production of additional carbon for the BECCS systems in not more a limiting factor, since it is possible to feed the biogas plant without lowering food & feed production.

At the same time, the biogasdoneright® platform technologies platform cuts starkly into the emission related to conventional agricultural practices.

Biogasdoneright® platform technologies land efficiency

The land efficiency of bioenergy systems can be defined as the quantity of primary energy that can be obtained from 1 ha of farmland used in substitution of first harvest crops used as food and/or feed (First crop land requirement FCLR)[34],and it is calculated after the following equation[35]:

(1) $$FCLR(ha) = \left(\frac{A-I}{C}\right) \times \frac{1}{P}$$

Where :

(2) $FCLR(ha)$ Is the amount of land (in ha) of first harvest crops that is necessary for the biogas production

(3) $A = \frac{MWh_{el}}{\eta}$ It is the primary energy (in MWh thermal energy) that need to be produced to satisfy the amount of electricity that we want to produce

(4) η It is the efficiency of the electricity generator

(5) $I = \frac{MWh_{th\ biogas}}{\eta}$ It is the primary energy that can be obtained from "integration biomass", perennial non-food lignocellulose feedstocks (PNF) produced on marginal lands, from agriculture byproducts (AW), from second harvest cover crops (CC), from livestock effluents (LW), from organic residues (OW)

(6) $C = \frac{MWh_{th}}{ton_{SOV}}$ It is a conversion factor that define the quantity of primary energy that can be obtained per DM ton of first harvest biomass

(7) P ha It is the productivity of first harvest in ton DM/ha

The amount of land needed is then not only influenced by the first harvest crops and their yields rate, but it is also influenced by the efficiency of the technological and biological conversion systems and in the case of biogas also by the primary energy supplied by other feedstocks (integration biomass).

30 Currently after three years of biogas plant production , the farm is still using some nitrogen chemicals fertilizers (20-30% on crop demand) because still now isn't available all the digestate spreading equipment needed to use digestate all year around. Concerning all the others macro and micro nutrients the farm is already independent from mineral fertilizers.
31 Stefano Bozzetto , op. citata.
32 Nitrogen utilization efficiency, Water utilization efficiency.
33 See slide the following paragraph for more explanation about the figures mentioned.
34 It will be shown later that competition food & feed versus bioenergy is true only if one exclusively grows energy crops. Through second harvests to produce for food & feed and also for bioenergy then there is no competition anymore. For this reason the FCLR parameter is taken into account as prevalent.
35 This equation has been adapted to the biogas and integration biomasses from the study of Lynd et al. "*Energy myth three – high land requirements and an unfavorable energy balance preclude biomass ethanol from playing a large role in providing energy services*" B.K. Sovacool and M.A. Brown (eds.), Energy and American Society – Thirteen Myths, 75–101. © 2007 Springer.

In our case then the equation is calculated as follows:

MWh el	8.600
η	40%
MWh th /year	21.500
I (MWh th)	21.080
(A-I)	420
C MWH th /ton OVS	3,19
P (ton/ha) Silage Sorghum	40
P (MWh th /ha)	42
FCLR (silage sorghum) ha	10

In fact the most of the primary energy needed for the production of 8.600 MWh electricity at the biogas plant derives from the use of what we define as integration biomasses[36]: cover crops and livestock effluents, as detailed in the AD feeding diet (see below).
Only the sorghum silage uses soil that is not in rotation with other food & feed crops, since the ha used in this case for the sorghum are not fertile enough to sustain a reasonable yield for second harvest.

EXAMPLE OF BIOGASDONERIGHT® DIGESTER FEEDING PLAN

DIGESTER DIET	**BIOGASDONERIGHT**			
	ton fm/day	*Nmc/day*	*ton / year*	*FCLR*
Wheat silage	3,7	814	1.350	0
Wheat grain	-	-	-	0
Nitrogen fixing Mix and triticale	5,8	1.093	2.100	0
Triticale	12,3	2.342	4.500	0
PARTIAL WINTER CROPS	**21,8**	**4.249**	**7.950**	**0**
Corn silage for the Stable	0,0	-		
Corn silage for the Digester	18,1	4.340	6.600	-
Corn grain	0,0	-	-	-
Sorghum grain	0,0	-	-	-
Sorghum silage	1,0	208	380	10
PARTIAL SUMMER CROPS	**19,1**	**4.548**	**6.980**	**10**
0			-	
0			-	
Chicken manure (eggs @30%DM)	10,0	1.200	3.650	-
Bovine manure	9,6	768	3.504	-
Bovine slurry	14,4	504	5.256	-
PARTIAL LIVESTOCK EFFLUENTS	**34,0**	**2.472**	**12.410**	**0**
	74,9	11.269	27.340	10

36 Integration biomasses are defined as the biomasses that today do not bring added value to the farmer and that can contribute to integrate the economics of the farm either reducing costs for their treatment (manure, by products, wastes) or utilizing better the soils with crops that would have no market.

BIOGASDONERIGHT CONCEPT CAN BE APPLIED EVERYWHERE

Anaerobic digestion: a technology applicable in all agroecological conditions

Analogues and even more interesting and far reaching examples for applying the biogasdoneright® platform technologies principles exist in areas with less human impact, less intensive agriculture, especially in drylands (200 to 600 mm rainfall per year).

A soil degrades for several different reasons, its recovery as fertile farmland requires crops able to adapt to that soil and increased soil organic matter to support farming. The availability of digestate and the flexibility of AD multi-feedstock diets make biogas production an essential tool to recover degraded agricultural soil. For example, dual purpose (forage and energy) CAM plants crops have a DM content that is ideal for the anaerobic digestion processes (8% DM is usually inside the digester). These crops have a WUE[37] and NUE that can be many fold higher than C3 and C4 plants (see table below), thus such plants are suitable also for fighting desertification or soil degradation where needed and where rainfall is low via land revegetation and nutrients and carbon cycling to soil via digestate[38].

Depending on water and fertilizers available, CAM crops can produce 20/60 ton DM/ha per year of biomass rich in accessible carbohydrates, either to be used coupled to a protein supplement as feed source or to be used in biogas production.

The flexibility of the biogasdoneright® platform technologies to its feedstocks coupled to the nutrient and carbon recycling into the soil via the digestate, make it a tool to replenish soils that today are marginally productive due to low organic carbon content.

The additional carbon demand for the energy and bio-based materials markets indicates that a market-driven approach is the best option to implement carbon sequestration from the atmosphere. We consider that the Italian biogas project has just started and there is still a lot of room for improvement, but we can say that based on our own daily experience that the people adopt it "spontaneously" since it costs less and it improves the cash flows. A simple feed in scheme was sufficient to trigger the whole process and also brought stability to a sector that suffers from commodity prices volatility. The Italian biogas demand kept the stables opened and kept them from closing during the low prices of the last three years. Very few ended their agricultural activities to work for a tariff paid by consumers. Cost reduction (no fertilizers purchased, no costs for livestock effluents disposal...), and cash flow improvements prompted us to look into producing for both food and fuel markets, so the farmers can earn more and our soils can become even more fertile by storing carbon from the atmosphere, a real triple win situation.

Table 47. Rain use efficiency (RUE) and water use efficiency (WUE) under rainfed and irrigated conditions for several crops

Crop	RUE (kg DM/mm/yr)	WUE - Transpiration coefficient (kg H_2O/kg DM)	WUE (mg DM/g H_2O)
Agave	45.0	93	10.7
Opuntia	40.0	267	3.7
Atriplex nummularia	28.0	304	3.3
Pearl millet	25.0	400	2.5
Barley	20.0	500	2.0
Sorghum	15.0	666	1.6
Wheat	13.3	750	1.3
Alfalfa	10.0	1000	1.0
Rangeland	5.0	2000	0.5

37 *The use of opuntia as a fodder source in arid areas of southern africa* - Gerhard C. De Kock
38 One of the target of the authors of this manuscript is to take the principles of the biogasdoneright as developed in the Po valley and adapt it to different, more interesting and challenging conditions wherre to increase substantially the food & feed production and the SCS. We plan to do so avoiding rigid models and instead find pragmatic solutions that fits best the local ecological and market conditions for the biogasdoneright to be unfolded.

The Sicilian case study [39]

In attachment is reported a case study for a farm in Sicily (project to be built), where the biogasdoneright® concept has been applied in a dry land area. The farm aims at producing 800-900 Nm3/h of raw biogas, thus circa 2,8 million kg of biomethane for road transportation.
The farm is located in the Enna province, in the heart of Sicily, and it has 550 ha of clay loamy soils with 1% of organic matter. The average rainfall is 600 mm/year but rains are not frequent and drought periods can be long.
The current crop rotation is based on durum wheat production, the main product of Sicilian agriculture since Roman time. To avoid low protein yield in durum wheat, it is rotated in succession with the "Sulla", the Italian Sainfoin plant, a nitrogen fixer native to the Mediterrenean area and resistant to intermittent droughts. But due to the local livestock industry crisis the farmers stopped the production of Italian Sainfoin silage and they left the farmland in set aside, with the known negative effects as and a further acceleration of its desertification process.

The biogas plant thus could be for this farm a game changer and allows the use of Italian Sainfoin as silage.

EXAMPLE OF ITALIAN SAINFOIN

Italian Sainfoin will be co-fed to the AD together with different agro and food by products such as waste streams of olive oil, citrus species, pulp and grapes marc from wine production. All these byproducts have still some sugars prone to ferment and when not properly handled can cause environmental pollution.

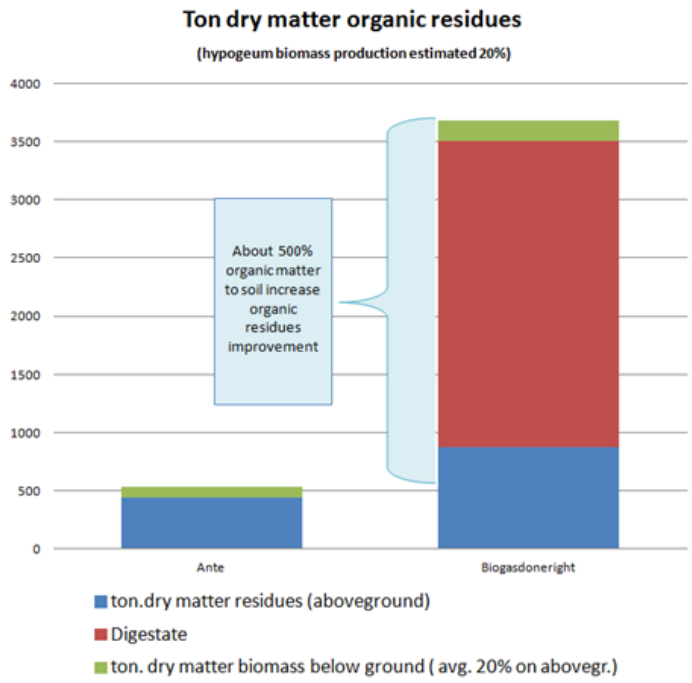
Sorghum in second harvest obtained via drip fertirrigation and also forage Opuntia complete the biogas feedstocks for this Sicilian plant.
The new crop plan is summarized in the figure below: the farm is able to produce 4.000.000 Nmc biomethane/year while reducing the land used for food production by only of 100 ha.

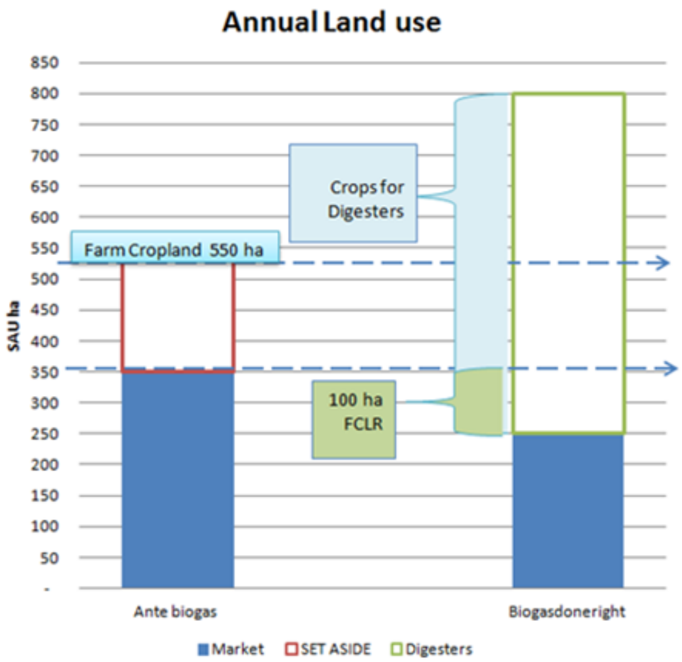
The administration of organic matter and nutrients to the soil is thus completely changed with the biogas plant, both for the crop rotation and for the digestate use.

The combined effects of an increased production of agricultural by-products, the utilization of the digestate, the increased soil coverage over the full year, are all prerequisites to significantly recover soil fertility. Soil organic matter inputs has been increased by five fold compared to the ante biogas situation, thus allowing the farm to become independent from fossil fertilizers, to produce for the market and for the digesters , and to improve the soil fertility and carbon content.
In the current conditions of the Mediterranean agriculture, where soils are under desertification and the rainfall is below 600 mm/year, the AD is a key technology to achieve an ecological agriculture intensification, to improve the economics of the farm and to recover soil fertility.

EXAMPLE OF CITRUS PULP CONTAMINATION

39 See ppt in attachment.


Ton dry matter organic residues
(hypogeum biomass production estimated 20%)
4000
3500
3000
2500
2000
1500
1000
500
0
About 500% organic matter to soil increase organic residues improvement
Ante
Biogasdoneright
ton.dry matter residues (aboveground)
Digestate
ton. dry matter biomass below ground (avg. 20% on abovegr.)


Annual Land use
SAU ha
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
-
Farm Cropland 550 ha
Crops for Digesters
100 ha FCLR
Ante biogas
Biogasdoneright
Market
SET ASIDE
Digesters

BIOGASDONERIGHT AS A TOOL TO ENHANCE SOIL CARBON SEQUESTRATION POTENTIAL

Soil and Land revegetation as carbon sink

The carbon emitted from soil and biota since the Industrial Revolution until now is about one third of that emitted over the same period by fossil carbon[40]. Many agricultural soils have lost the 50-75% of their earlier carbon stock. Many degraded and under desertification lands contain low carbon in their soils and in their surviving vegetation. These environments are "nearly empty sinks" in which to permanently store carbon at the scale required of at least 1 Pg of C per year [41].

The authors of this manuscript are convinced that is possible to sequester and store even higher amounts of carbon. At least 1,5 billion ha under desertification can be recovered to farmland via CAM plants, nitrogen-fixing trees, perennial cultures, floating water plants fed with digestate and other emerging technologies : soil sequestration of photosynthetic carbon could be the easiest BECCS system to implement on a global, diffused scale.

We are not prepared yet to present a peer-reviewed metric, but it is on our opinion that in the carbon cycle only soil biota could store the 100-200 Pg of carbon[42] that we need to bring CO_2 air concentrations below 350 ppm as many scientist require to avoid climate change risks[43].

This forecast is based on the conservative extrapolation of our empirical data collected in recent years.

We are currently engaging an international group of experts to challenge our calculations and then we will publish our findings in peer-reviewed journals.

Soil carbon sequestration: a low cost and effective solution

Sequestration of carbon in the soil is a fundamental process that is needed even without climate change. This is because soil carbon plays a cardinal role in our ecosystem spanning from enhancing soil biodiversity, improving water conservation in soils and enhancing soil fertility and the NPP of ecosystems.

The soil-amending properties of carbon enable the storage of carbon in these soils, after a start-up phase, grow and diffuse rapidly since the costs of capture and storage will be paid back by the cash flow generated in form of energy and/or biomaterials and also the increased NPP due to the enhanced soil fertility. Moreover, agricultural soils, thus the sink for carbon sequestration, are diffused almost everywhere on the planet and the practices and techniques involved in the biogasdoneright® platform technologies are easy to learn and apply at any level.

Organic matter in the soil is subject to oxidation, leaching and mineralization. Even when the best agricultural practices are in place (no tillage, drip irrigation, manure distribution, cover crops and residue inputs, nitrogen fixing crops in rotation, etc.), every soil is subject to oxidation of the organic matter (OM) and reaches its own equilibrium (plateau effect), where it cannot store more additional carbon. Increased OM happens provided that such supply is continuous until a new equilibrium is reached. Until this new equilibrium is reached, the farmland is able to store[44] the amount of carbon needed to avoid abrupt climate change scenarios.

Trials of long term manure administration prove that when a constant supply of OM is added, the soils can store a significant amount of carbon compared to soils where only chemical fertilization is used. Organic farming has demonstrated already that an increase of carbon in soils has a positive effect on farming.

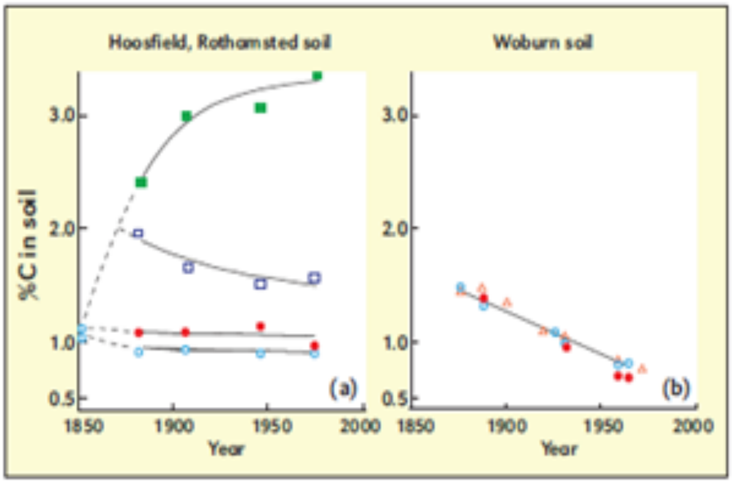


Figure 2. Changes in %C in the top 23 cm of soil at Hoosfield, Rothamsted (a) growing barley each year with annual treatments since 1852; unmanured ○, NPK fertilizers ●, 35 t/ha FYM ■, 35 t/ha FYM 1852-71, none since □; and Woburn (b). Cereals each year since 1876 unmanured ○, NPK fertilizers ●, manured 4-course rotation △.

40 "Soil carbon management and climate change" Rattan Lal 10 Apr 2014.
41 Lal et al. "Soil carbon sequestration"
42 Upside (Drawdown)The Potential of Restorative Grazing to Mitigate Global Warming by Increasing Carbon Capture on Grasslands, Seth Itzkan, 2014
43 Hansen James "tipping points. A perspective of a climatologist" 2008 http://www.columbia.edu/~jeh1/2008/StateOfWild_20080428.pdf , and Hansen 2013 op. cit.

What we know for sure, due to our first-hand experience as farmers and by experiments that stretched over decades is that continuous administrations of organic fertilizers are able to increase the organic matter of the soils.
The soil carbon sequestration is often source of discussion[45] among scientists, due to the challenges presented by the standardization of practices that are tailor made for specific soils and conditions.
Production of additional carbon and the presence of stable carbon in the solid fraction of the digestate (mainly lignin and undigested cellulose), help to overcame these hurdles. The production of biochar from the solid fraction of the digestate to mimic manure fertilization, could help further.

Lal[46] and others have confirmed that the potential of carbon sequestration in soils can occur at the scale needed to prevent an abrupt climate change scenario "The potential of Soil Organic Carbon (SOC) sequestration is finite in magnitude and duration. It is a short-term strategy to mitigating anthropogenic enrichment of atmospheric CO_2. The annual SOC sequestration potential is only about 1,2 Pg C/year. The atmospheric concentration of CO_2 at the observed rate of 1990 (3.2 Pg C/ year) will continue to increase at the rate of 2.0–2.6 Pg C/year even with soil C sequestration. Thus, a long-term solution lies in developing alternatives to fossil fuel. Yet, SOC sequestration buys us time during which alternatives to fossil fuel are developed and implemented. It is a bridge to the future. It also leads to improvement in soil quality. Soil C sequestration is something that we cannot afford to ignore".

These scholars should perhaps consider that the principles of the biogasdoneright® platform can significantly increase organic carbon primary production via increased biomass yield per hectare. Thus even lands that today are marginal or under desertification can store carbon in quantities that are today underestimated.

Soil carbon sequestration (SCS) bottleneck

The criticisms[47] and doubts regarding SCS as tool for combatting climate change have three main aspects:
A. Carbon in soils in not stable, can be subject to oxidation, leaching and erosion.
B. The carbon in soils reaches a plateau where further improvement of NPP decreases until it is negligible.
C. Continuous addition of external OM is needed to maintain or increase the carbon stored in soils.

The strongest argument used against organic farming is that increased carbon in the soil of organic farms is obtained by administering more manure than the average of conventional farming[48]. But this criticism is overcome if we able to increase NPP with additional carbon stored and simultaneously produce more residues and digestate to continuously increase the quantity of carbon input to the soil.

But an additional carbon production cannot be reached with the current agriculture practices. The agricultural sector is responsible for about 12% of the current GHGs emissions[49], this means that any further increase of photosynthetic activity on the planet (NPP increase) must be decoupled from today's conventional agricultural practices, and especially by reducing GHGs (CO_2, CH_4, N_2O) derived from farming and livestock management and also without reducing farmland to produce food & feed or reducing the carbon existing in natural biota (e.g. via deforestation to produce new farmland).

How to reach these targets? How to overcome hurdles and bottlenecks? How can the biogasdoneright® contribute to this targets?

The application of the biogasdoneright® platform technologies offers us multiple solutions to these problems:
- Additional carbon beyond carbon needed for food & feed can be produced, and this additional carbon can be stored in soils.
- The land efficiency of soils under degradation can be improved, not only increasing harvest yields, but also via higher soil coverage (using catch crops) and afforestation.
- The emissions linked to livestock industry can be mitigated using livestock effluents for the AD and at the same time using the digestate originating from the additional carbon production to decouple organic fertilization from entire reliance on livestock manure. In this way the SCS can be independent from livestock effluents production increase.
- The biogasdoneright® platform technologies can be seen also as a cleantech able to take effluents and byproducts from different industries (abattoirs, food industry by-products and waste, etc) and cycling them into biogas and digestate.
- Since all these measures make farming more cost-effective, once the practice becomes wide spread and better known, such techniques will be spontaneously adopted by farmers. Farmers will see first-hand from

44 The experience of Hoosfield Rothamsted farm is a flagship of organic farming for the length of the experiment (from 1852 until nowadays).
45 " Soil carbon sequestration to mitigate climate change: a critical re-examination to identify the true and the false" D. S . P owl s o n , A. P . Whitmore & K. W. T . Department of Sustainable Soils and Grassland Systems, Rothamsted Research, Harpenden, Herts AL5 2JQ, UK
46 R.Lal " Soil carbon sequestration to mitigate climate change"
47" Powlson et al. op. citata
48 Gattinger "Gattinger A, et al. (2012) Enhanced top soil carbon stocks under organic farming. Proc Natl Acad Sci USA 109(44): 18226–18231.
Leifeld "Organic farming gives no climate change benefit through soil carbon sequestration"
Gattinger "Reply to Leifeld et al.: Enhanced top soil carbon stocks under organic farming is not equated with climate change mitigation"
49 http://www3.weforum.org/docs/WEF_IP_NVA_Roadmap_Report.pdf McKinsey & Company 2010

others how the NUE and WUE improve, and how soil fertility is enhanced along with the positive effects of reduced production costs arising from lower (zero or near to zero) input of fossil resources.

- Part of the additional carbon produced must find different markets than food & feed traditional outlet, to reduce food market price volatility and improve farmer profit margins. Bioenergy and biomaterials are one option to diversify farm outputs and attract investments in the primary sector, investments that are today undersized for the challenges that are ahead of us (food security, climate change, etc etc) due to the low financial returns that the primary sector usually offers to investors. In other words, these technologies must improve the cash flows of farms. In this way the adoption of SCS can be progressively decoupled from carbon tax measures or long term incentives.

In the proposed scheme, the biogasdoneright® platform technologies act as a BECCS system through the Soil Carbon Sequestration.

Moreover, the biogas plant must be considered as a technological platform into which other carbon sequestration solutions can be plugged in, for example:

- Production of biochar starting from the solid fraction of the digestate with the goal of prolonging the presence of the carbon in the soil.

- Perhaps utilizing the CO_2 present in the biogas in methanation processes with the H_2 produced via renewable resources (Power to Gas concept) and even the production of CO_2 derived industrial products (plastics, fertilizers, chemicals etc).

In order to grasp the scale of which a typical biogas plant operates, a carbon balance is helpful. For a 1 MWe plant circa 16 kton vegetable biomass is needed yearly. This input corresponds to circa 2,5 kton organic carbon, and as outputs from the digesters we obtain about

A. 1,1 kton carbon in the biogas as methane (44% of input carbon)

B. 0,9 kton carbon in the biogas as CO_2 (36%)

C. 0,5 kton carbon in the digestate (20%)

Beside the traditional organic fertilization practices, the biogas refinery concept offers us further and innovative ways for carbon sequestration and can provide an even bigger impact[50] in terms of fixed carbon and additional carbon negative systems.

In this respect, two main strategies can be followed to increase the sequestration capacity of a biogas plant:
- Biochar production from the solid fraction of the digestate
- Reuse of CO_2 in the biogas to produce further biomass or by solar/wind fuels or biobased products

Biochar from solid digestate

The pyrolysis of the solid fraction of the digestate to produce a more stable form of carbon (black carbon) in form of charcoal is a very promising technique[51].

The production of organic and mineral fertilizers from the two digestate fractions (the biochar from the solid and the nutrients in the liquid fraction) could give a higher added value especially for the soils that suffer erosion and lower fertility due to unsustainable farming practices or natural desertification, or to improve organic content in the sandy soils. The production of black carbon from biochar[52] must be achieved using additional carbon. Black carbon contributes synergistically to increased soil fertility by recycling digestate nutrients back to the soil.

- Table 1. Specification of digestate and biochar (Troy et al., 2013).

Parameter	Digestate (solid phase)	Biochar from digestate
Water content ($g\ kg^{-1}$)	85	53 ↓
Volatile substances ($g\ kg^{-1}$ d.m.)	697	226 ↓
Black carbon ($g\ kg^{-1}$ d.m.)	81	262 ↑
Ash ($g\ kg^{-1}$ d.m.)	222	512 ↑
N ($g\ kg^{-1}$ d.m.)	45	38 ↓
C ($g\ kg^{-1}$ d.m.)	452	338 ↓
H ($g\ kg^{-1}$ d.m.)	51	10 ↓
O ($g\ kg^{-1}$ d.m.)	219	-
H/C mole ratio	1.37	0.34 ↓
HHV ($MJ\ kg^{-1}$)	19.1	11.3 ↓

Even for a promising technology like biochar the first bottleneck to overcome in order to become a carbon negative option is the availability of additional carbon to be sequestered. The two processes then (the biochemical AD and the thermochemical biochar formation) applied in sequence offer interesting synergies with great potential[53].

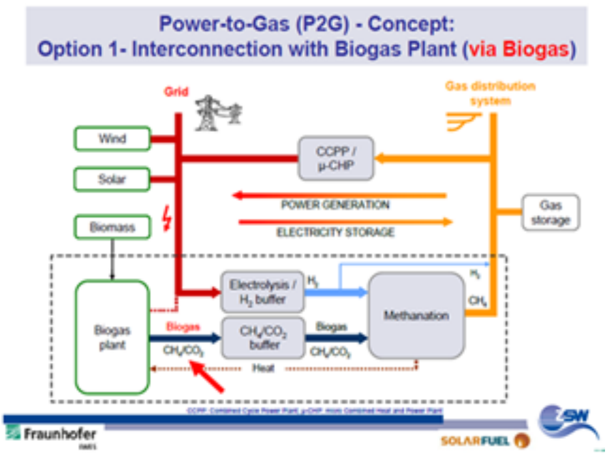
It is still too early to assess the economics of the process and more specifically if the extra costs for the pyrolysis are covered by the effects of the biochar on the soil fertility and bioenergy additional production (tar oil, heat, etc).

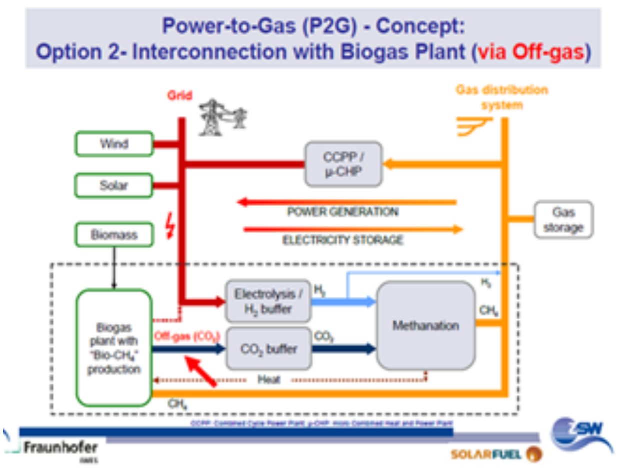
50 That represents a multiple of the sequestrated carbon (thus avoided) of the biomethane in the biogas, following the usual approach of mitigation of emissions of GHGs from fossil fuels, the so called avoided emissions.
51 http://www.imp.gda.pl/BF2014/prezentacje/3_Wioleta_Radawiec.pdf
52 "Sustainable biochar to mitigate global climate change" Dominic Woolf, James E. Amonette, F. Alayne Street-Perrott, Johannes Lehman & Stephen Joseph
53 See on this subjet among others http://www.jove.com/pdf/51734/jove-protocol-51734-evaluation-integrated-anaerobic-digestion-hydrothermal-carbonization
54 http://pubs.rsc.org/en/content/articlelanding/2014/cs/c4cs00035h#!divAbstract

CO_2 biogas reuse

The CO_2 contained in the biogas can also be tapped as a feedstock for different purposes or processes.

- Geological or mineral sequestration (with the use of different approaches)
- Methane production via Power to Gas integrating thus at the farm site decentralized renewable fuel production with the CO_2 contained in the biogas[55]





- Production of biomaterials (fertilizers such as ammonium carbonate, biopolymers such as PHA and a whole array of processes that aim at the use of CO_2 as feedstock are arising [56])
- Biofixation, especially through aquatic plants. Aquatic plants bear the potential for further carbon and protein additional production, adding a multiplier effect in carbone negative performances. Plants such as Azolla can play an important role in the near future for recycling the CO_2 and the digestate of the biogas.
- Problems that hamper the deployment of microalgae technology are well known [57] and among them are high energy input for product harvest, possible contamination of zooplankton and others reason make the production costs of microalgae sometimes magnitude higher than the production of terrestrial biomass.
- The cultivation in set aside land of aquatic plants is promising for many different reasons summarized here below:

Possibility to use the liquid fraction of the digestate upon dilution (30-50%)

  - Possibility to increase the photosynthetic activity via CO_2 fertilization with CO_2 from the biogas
  - No need for stirring since they are floating plants,
  - Possibility of easy harvest with very low energy input for their floatability and dimension.
  - Robustness of the plants toward cultivation and high yield in dry matter per hectare
- Use of CO_2 as sole carbon source to produce most of the chemicals we know today via metabolic engineering of Cyanobacteria[58]

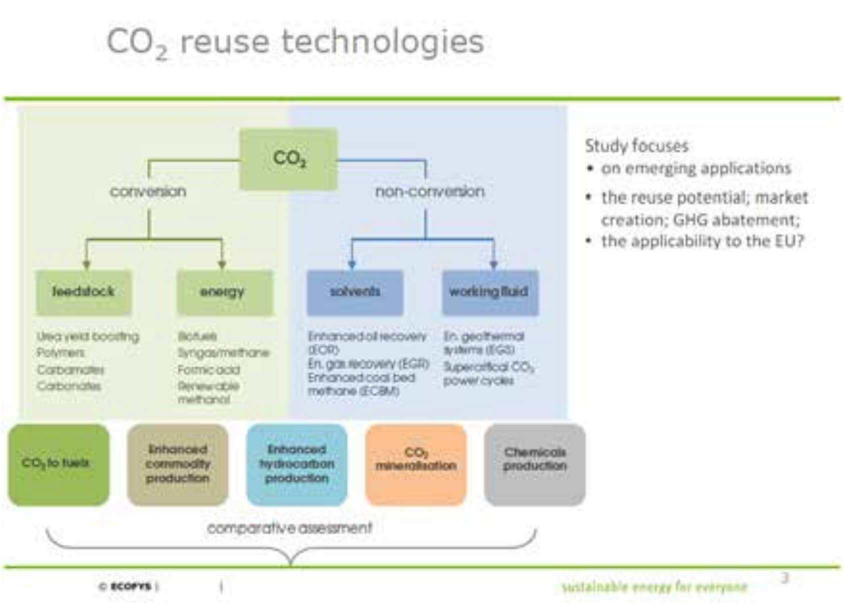
The P2G technologies point toward the integration of "no fuel" renewable energy sources and CO_2 using renewable hydrogen as link to it via methanation processes.
Production of renewable methane integrates the gas grid with the electric grid and the seasonal storage of the energy harvested via wind mills or solar panels, not to mention the use of PtG to produce a zero emission fuel such as biomethane to be applied in road transportation[59]. Keeping in mind that the raw biogas on average contains 55% of CH_4 and 45% of CO_2, it is easy to understand that upgrading the CO_2 to CH_4 would mean almost doubling the yield of biofuel produced per ha of farmland.
In a 100% renewable energy scenario, the biogas plays also a pivotal role as CO_2 supplier for synthetic fuels (fuels made from CO_2 and H_2, such as methane but also butanol from CO_2 and sunlight[60]). From this perspective the biogas supplies cheap, easy and distributed access to CO_2 with several advantages over other CO_2 capture processes (post combustion, oxyfuel, direct air capture...)

55 www.krajete.com/ www.electrochaea.com/ www.audi.com/com/brand/en/vorsprung_durch_technik/content/2013/10/energy-turnaround-in-the-tank.html
56 Catalysis for the Valorization of Exhaust Carbon: from CO2 to Chemicals, Materials, and Fuels. Technological Use of CO2 Michele Aresta, Angela Dibenedetto, and Antonella Angelini Chem. Rev., 2014, 114 (3), pp 1709–1742 DOI: 10.1021/cr4002758
57 http://energy.gov/sites/prod/files/2014/06/f16/naabb_synopsis_report.pdf) https://www.youtube.com/watch?v=O34gTsxyDq8
https://www.youtube.com/watch?v=44loaNhxoEI
https://www.youtube.com/watch?v=EG1adlKF2D4
58 http://phytonix.com/ http://photanol.com/
59 A perspective on the potential role of biogas in smart energy grids, Tobias PERSSON e others, 2014, http://www.iea-biogas.net/files/daten-redaktion/download/Technical%20Brochures/Smart_Grids_Final_web.pdf
60 Ibidem

All these technologies are just part of the biogas refinery concept as we intend it because the sum of these two carbon sources is higher than the quantity of carbon in the biomethane.

Together with the carbon that remains in the soils via the root residues and the agricultural leftovers, the biogas can play an impact in the carbon negative technologies via the carbon sequestrated in the soils, in other biota or in tailor-made materials from CO2.

PROSPECT OF POSSIBLE CO2 RECYCLING TECHNOLOGIES AVAILABLE



ANAEROBIC DIGESTION AND SOIL CARBON SEQUESTRATION: TOWARD CARBON NEGATIVE AGRICULTURE PRACTICES

In the proposed scheme, the biogasdoneright® platform act as a BECCS system through the three CCS steps:

- Capture, through photosynthesis by producing additional carbon in land already cultivated , or in marginal lands,
- Transport
    - Through the anaerobic digestion process regarding the carbon spread on the fields (directly or through the solid digestate converted in biochar)
    - Through the organic carbon in the above and below ground part of the plants that are left on the fields
- Sequestration through the organic fertilization of the soils and the even through a series of technologies that will be available in the next decade (Power to Gas, biochar, bioplastics...)

All the above-described measures can happen at near zero costs, without asking for special rules or laws from the policymaker, although a transitory phase where incentives and "compulsory mandates" are given to help market penetration and projects bankability, speeding up the transition from conventional agriculture toward "**carbon negative agriculture**".

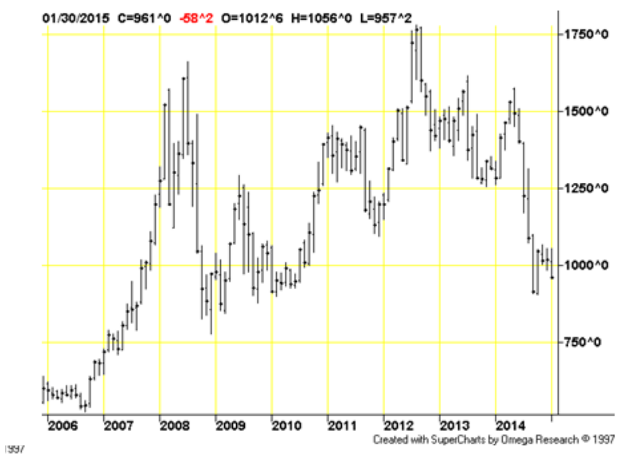
The costs for capture and sequestration of CO_2 can thus be paid for by the increased fertility and output at the single farm level and by improving the economics of the farm. The biogas makes the farm independent of fossil fertilizers and energy purchases, thus making the farm able to produce in a more competitive way and also able to sell its outputs at more predictable prices, less subject to the fluctuations in fossil energy prices. Moreover, from the farmer's perspective, diversify the sales in the energy and biobased material markets, besides traditional food & feed markets, mitigates risks due to volatile food prices and strengthens his cash flows. **This is an essential prerequisite for a revolutionary transition of the current conventional agricultural system to a carbon negative agricultural system**. Also, the increased global food production that will be needed in the next decades is necessarily linked to more investments in agriculture. Such investments are today risky for the investors since food prices have been stagnating in the last 40 years[61], except some recent spikes (2008 & 2011) , worsen the investor interest in the primary sector.

The following recent quote from the Director-General of the FAO is particularly relevant at this point:
"*In the past decades there have been a lot of debates about the priority and food versus biofuel production.* ***But nowadays we need to move from the food versus fuel debate to a food and fuel debate.***

EXAMPLES OF PRICE VOLATILITY OF TWO OF THE MOST TRADED AGRICULTURAL COMMODITIES

Corn CBOT prices (2015 Jan 31st)

Soy CBOT prices (2015 Jan 31st)



There is no question that food comes first.
And there is no question that biofuel should not be simply seen as a threat. Or as a magical solution.

Like anything else, it can do good or bad. We have seen successful and sustainable biofuel production systems that provide an additional source of income for poor farmers.
It is well known that the use of maize and oilseeds for biofuel production helped push agricultural prices higher in the food prices spike that began in 2008.
However, in more recent years, the demand for biofuels has supported food prices.
It acted as a support for those crops creating a buffer zone and avoiding that agricultural prices fell to the point that

61 FAO Food Price Index in real and nominal terms

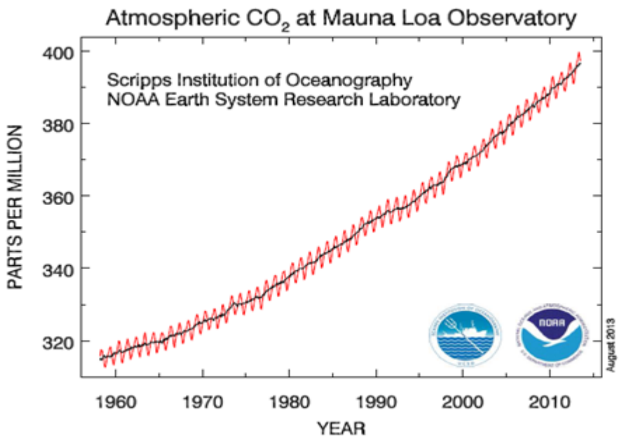
farmers would be discouraged to produce next year. Biofuels create additional demand for agriculture products, including cereals in countries with long supplies, ***which helps farmers in developing countries.***"[62]

We agree with Director-General Graziano Da Silva: after decades of undisputed fossil use domination in agriculture, the biogasdoneright® platform technologies concept is helping us reposition the primary sector at the center of the innovation needed to sustain many billions of people on this planet of finite resources.

The biogasdoneright® carbon and land efficiency impacts allow us to simultaneously increase NPP, implement large scale Soil Carbon Sequestration (SCS), and produce carbon negative biofuels for the internal combustion engine (ICE) and hopefully biomaterials in a near future.

In our view this is a carbon negative technology that can be deployed today without the need for expensive or cumbersome new infrastructure or research. The majority biogasdoneright® technologies are ready to implement today.
The biogas refinery can bring the farm back to the center of economic development since a farm that has no need to buy fertilizers or fuels will become a more stable and safer investment. Anaerobic digestion is a tool that allows a real ecological agricultural intensification and regenerates soils under desertification or degradation. It is thus a win-win strategy to tackle CO2 emissions and climate change that we cannot afford to ignore.

The Keeling curve tells us that every summer the CO2 concentration decreases, since the Northern Hemisphere has more land, thus more photosynthetic capacity. We need in every way, as quickly as possible, to expand the planet's photosynthetic activity, via additional carbon production at the scale required to address climate change, thus we will bring more and more carbon from the atmosphere into the soils or elsewhere in the biota.



We consider the experience of the Italian biogas[63] industry as just beginning and there is still much room for improvements, but from our own daily experience we know that farmers adopt it spontaneously since it costs less and improves their cash flows.

A simple feed in tariff law was sufficient to trigger the whole process and also brought stability to a sector that suffers from commodity price volatility. The Italian biogas industry kept many dairy stables open during the low prices market crisis of the last three years. The Italian biogas industry is now the third largest producer in the world (after Germany and China). Cost reduction (no fertilizers purchased, no cost for livestock effluents disposal...) and cash flow improvements prompted us to consider producing for both the food and fuel market, so the farmers can earn more and our soils become even more fertile storing carbon from the atmosphere, a real triple win situation.

The development of technologies and their social acceptance (by NGOs, politicians, environmentalists, organic farmers...) have helped us go even further and apply the biogasdoneright® platform experience not only in the fertile food-productive Po Valley or in the Lands of Chianti and Parmigiano Reggiano, but also in those semi-arid lands of Sicily, a former Roman Empire breadbasket, where durum wheat is nowadays cultivated in soils with less than 1% organic matter content, and where the current market value is nearly half of Manitoba durum wheat imported by Italian Maccheroni factories.
If we look globally we can see how these principles could be applied broadly, from the steppic hills of Tunisia or Algeria, to the dry climates of the North-East Brazilian plains, where inspired agronomists are obtaining impressive results by intensive cultivation of cacti[64] ,that have great potential for being converted into biomethane or into feeds for cattle and swine.

62 http://www.fao .org/about/who-we-are/director-gen/faodg-statements/detail/en/c/275129/ Global Forum for Food and Agriculture, 2015 FAO Working Meeting "Addressing Food Security Challenges under Increasing Demand for Land, Soil and Energy" Opening statement by FAO Director-General José Graziano Da Silva 16 January 2015, Berlin, Germany
63 4 Billion € invested in the last 5 years, 1.000 biogas plants at farm site, 7,5 TWh electric energy produced per year, more than 30 million m3 digestate per year, 12.000 new green jobs and third in the world after China and Germany.
64 http://www.bioone.org/doi/abs/10.2111/08-226.1?journalCode=rama

OUR MOTIVATIONS

"A cool planet and full plate"[65] is possible:

- **Let produce additional carbon via agricultural ecological intensification and revegetation of set aside land**
- **Let transform the additional carbon production into a material to enhance soil fertility and store more organic carbon in the soil, thereby decoupling organic fertilization by livestock industry growth**
- **Let diversify agricultural output in the Food, Feed AND Energy and biomaterials markets, In this way such services and products will attract more and more investments in agriculture and in organic soil fertilization via digestate. This will lead to an increased food and feed production, an increase in renewable bioenergy and especially an increase in Soil Carbon Sequestration.**
- **Let Biogasdoneright® thus become a key tool to accomplish widespread low cost and sustainable BECCS as IPCC recommended.**

65 Parodying the recent Lester Brown book "A Hot Planet and Empty plates", that taking an orthodox malthusian approach to development banishes bioenergies to a negative role in sustainable food production.

David Bolzonella
Associate Professor of Industrial Biotechnology, University of Verona

Stefano Bozzetto
Executive member of European Biogas Association, Farmer and Biogas producer

Bruce Dale
University Distinguished Professor, Michigan State University

Paolo Foglia
ICEA - Institute for Ethical and Environmental Certification

Piero Gattoni
President of the Italian Biogas Council, Farmer and Biogas producer

Paolo Inglese
Full Professor of Agriculture science, University of Palermo; Director of Cactus net at FAO

Biagio Pecorino
Full Professor of Agriculture economy, University of Catania, Farmer and Biogas producer

Fabrizio Sibilla
Scientific advisor at Italian Biogas Council

Ezio Veggia
Farmer and Biogas producer, Vice president at Confagricoltura

Lorenzo Maggioni
Italian Biogas Council, responsible for Research & Development

Guido Bezzi
Italian Biogas Council, responsible for Agriculture

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Giovanni Battista Zorzoli
Engineer, expert on Renewable Energy

Francesco Ferrante
Vice President of Kyoto Club, Italy

Gianni Silvestrini
Scientific Director of Kyoto Club, Italy

David Chiaramonti
Contract Professor of Biomass Energy Conversion Processes and Technologies, Florence University

Susanna Pflüger
Senior Policy Advisor of European Biogas Association

Arthur Wellinger
European Biogas Association co-founder and honorary member

ANNEX

Biogas and sustainable farming

Could we achive a sustainable farming without biogas ?

agr. eng. Stefano Bozzetto

Bozzetto@European-biogas.eu

Consorzio Italiano Biogas

EBA 2014 Conference - NL

Bioenergy is controversial

- Bioenergy looks like a controversial issue concerning
  - Food security
  - With 9 Billion people we can't feed people, animals and cars, we need to choose....
  - Then, using food crops to fuel cars is *immoral*
  - Using food crops for fuel increase the agricultural commodity prices
- *Agricultural land is a limited resource*
  - We can't use more land for agricultural production: either we produce food or energy
  - *We have to choose!*

"[I]t's a crime against humanity to convert agricultural productive soil into soil… which will be burned for biofuel." (Jean Ziegler, UN Special Rapporteur, 2007)

The Lawyer Tim Searchinger

"Bioenergy is a carbon loser"

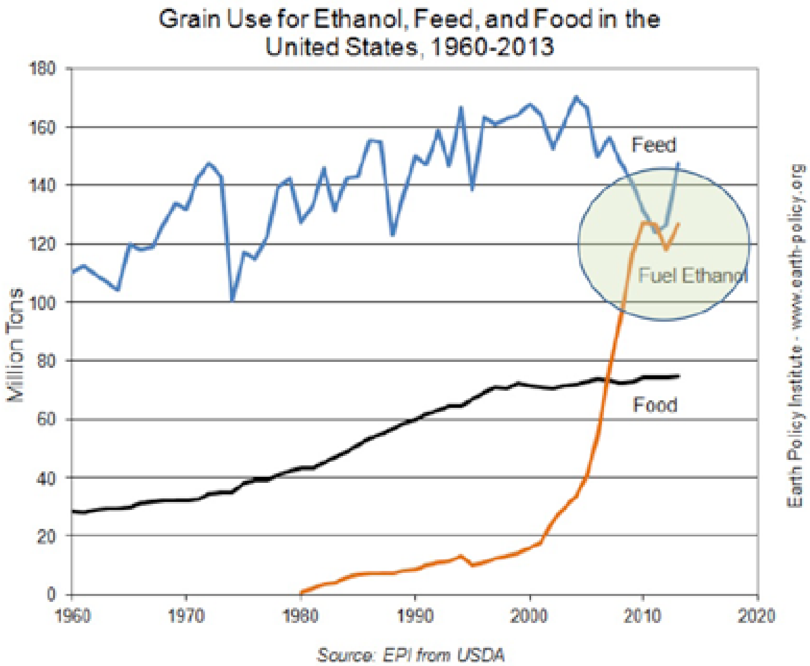
- *"Bioenergy is more polluting than coal "*
  - because carbon for bioenergy purposes would in any case be seized for feeding purposes
  - *"There's a mistake in the emissions calculation from bioenergy"*
  - *"With bioenergy there is no extra removal of carbon"*
- In US and in EUROPE a legal process is being developed to burden biofuels with a **carbon debt** for undesired effects deriving from their growing **(iLUC)**

- Searchinger, T., (2010) "Bioenergy and the Need for Additional Carbon," *Env. Res.*

Consorzio Italiano Biogas 3

The Claim

Biofuels production out place food and feed production



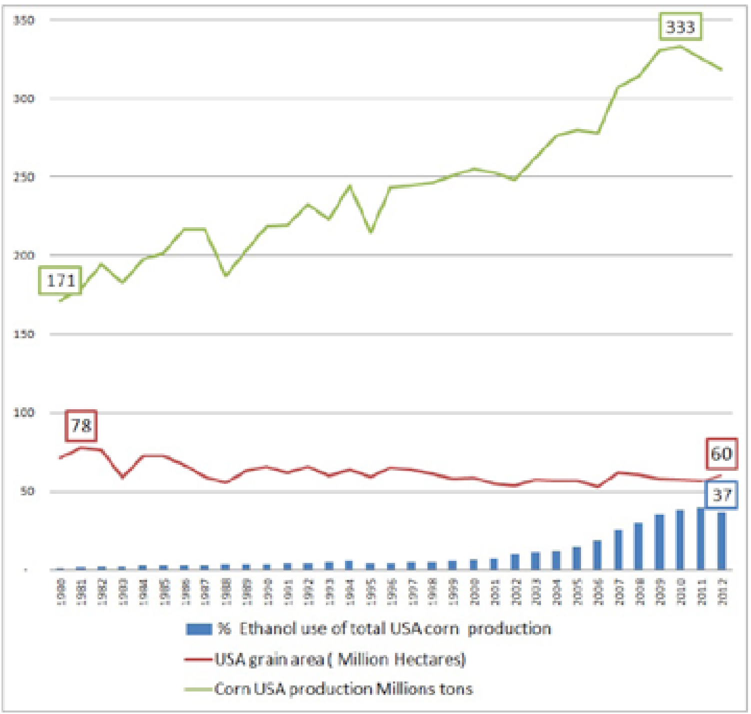
http://www.earth-policy.org/data_center/C24

20 -09-2014

Consorzio Italiano Biogas 4

The facts

- Ethanol corn consumption increase from 0% to 37% of corn usage from the ‘80
- But in the maintime US **corn production doubled**
- and US **grain agricultural land** used is **nearly stable**



http://www.earth-policy.org/data_center/C24

Consorzio Italiano Biogas

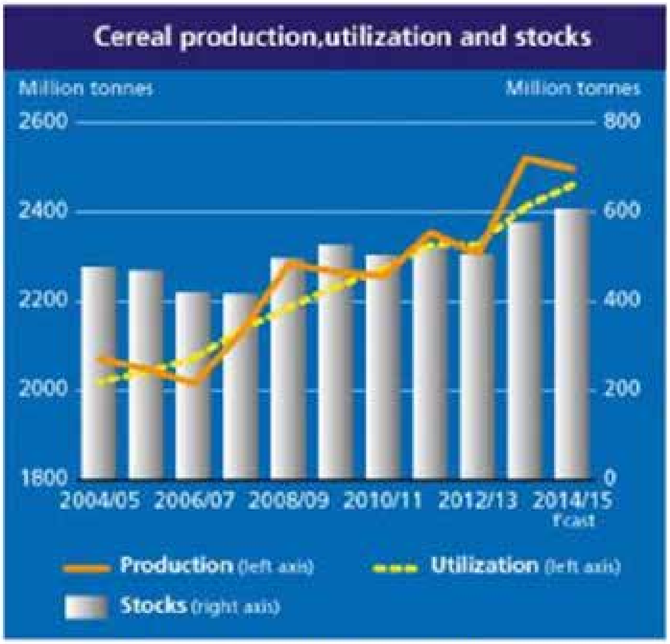
5

The Claim

Biofuels threaten food safety

The facts

2014 world cereal stocks are growing up at historical levels



http://www.fao.org/worldfoodsituation/csdb/en/

20-09-2014

Consorzio Italiano Biogas

6

The Claim

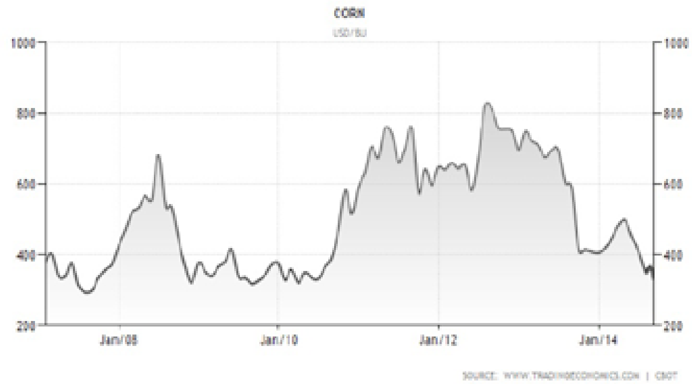
The biofuels boost commodities price

The facts

- **What should the international corn 2014 price without US corn ethanol demand be?**
  - Current corn prices are at historical low levels
  - So, to protect thousands of European farmers from bankruptcy....

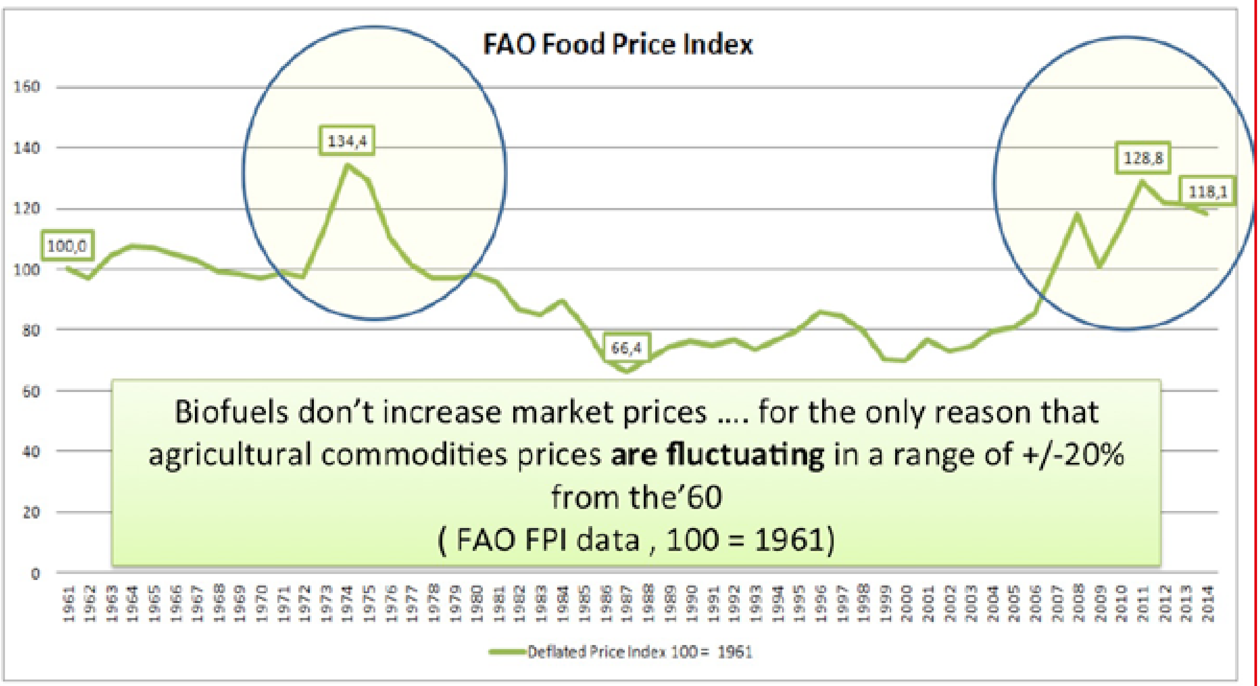
    *"The European Commission has announced that the **import duty on maize,** sorghum and rye is to be set at **10.44 EUR/tonne**. The decision is based on the basic Regulation and comes in response to the situation on the world markets for maize and the resulting low prices"*

CBOT August 2014 Corn price low record



http://www.tradingeconomics.com/commodity/corn

Finally...



"The FAO Food Price Index fall to its lowest level since September 2010 "
Release date: 11/09/2014 http://www.fao.org/worldfoodsituation/foodpricesindex/en/

How to get more food in a sustainble way

- EU parlament will soon be called to approve the ILUC RED modifications
- **Are we sure that iLUC is the right policy to achieve food security in a sustainable way?**

- In a carbon costrained world, with a Planet with 9 Billion more *affluent* people, can we produce more food in a sustainable way without biogas?

Consorzio Italiano Biogas 9

What are the right questions that a MEP should ask while amending RED in biofuels?

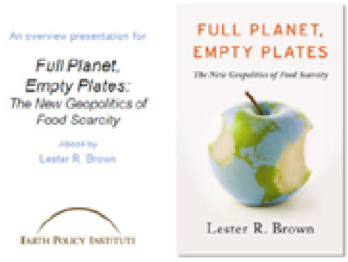
- Can we have an ecological agricultural intensification without biogas?
- How can we have fossil energy/ fertilizers **independent farms** without the use of **digestate and biomethane** to fuel tractors and agricultural machineries?
- Can we achieve **green compliance** obligation in a cost effective way from ACP without biogas?
- Why does **greening** have to be achieved by reducing farmers turnovers? Doesn't this harvest decrease regard ILUC theory?

- To improve Food Security, **how can we spur new investment into agricultural sector** with current food/ feed price market volatility without energy cash flow support and market diversification coming from bioenergy and bio-based markets?
- Can we have a "**bio-economy**" without carbon based renewable resources?
- Can we have a **negative emissions** energy system to drag CO2 from atmosphere without bioenergy as IPPC is requering in the last "Mitigation report 2014"?
- Or **less costly C-capture technologies** than bioenergy to prevent the Planet from abrupt Climate Change scenarios?

Consorzio Italiano Biogas 10

An "ecological agricultural intensification"

- The unavoidable issue, which even Europe has to face is that:
  - we have to keep producing more in agriculture
  - but we have to be able to do this in a more sustainable way and at the same time reducing production costs
- We need an "**ecological agricultural intensification**"
  - Producing more on the same land
  - Not using fertilizers or fossil energy
  - Increasing land fertility and its carbon sink potential
  - Reducing the impact of modern agriculture on water and air
  - Fostering biodiversity in the country with greater crop diversification



Consorzio Italiano Biogas 11

An"ecological agricultural intensification" (2)

- Agriculture needs greater investments and new technologies, such as biogas, to ensure
  - Increased output production from the same land
  - With less polluting practices
  - Lower production costs, starting from cutting modern agricultural dependence on fossil fertilizers and fuels
  - by making farm cash flows more reliable, also through market diversification (by placing energy and bio-based material markets alongside traditional food and feed markets)

Consorzio Italiano Biogas 12

AD and sustainable farming

- A biogas plant modifies the technical and economic standpoint on which a farm may reconsider its development policies
- A biogas plant is something more than renewable power or fuel

AD is an essential "**technological infrastructure**" on any farm or on any agro-ecological area to carry out a sustainable (r)evolution in agricultural practices

- Biogas offers a professional farm several and diverse opportunities to improve production in a sustainable manner:

1. We can produce crops for the digester without reducing seeding productions for the food and feed market, improving the photosynthetic efficiency of fields by **increasing annual crop coverage**
2. We can grow crops **without using fossil fuels and fertilizers**
3. We can **diversify cash flows** by producing ALSO for the energy markets and biobased industry
4. Better cash flows mean **greater credit standing** for farms so as to have tools to sustainably innovate crop and breeding techniques regardless of regulations or agricultural and environmental aids, **simply because it costs less**

Consorzio Italiano Biogas 13

The current agricultural production systems are unsustainable and unprofitable

TO PRODUCE MORE FOOD IN A SUSTAINABLE AND COMPETITIVE WAY

WE NEED

#biogasdoneright*

too

•We have been inspired by the researchers Lee Lynd, Bruce Dale , etc. that we would like to thank publicly. In particular the "biofuels done right "concept wast for the first time elaborated by Bruce Dale and Others "***Biofuels Done Right***: Land Efficient Animal Feeds Enable Large Environmental and Energy Benefits" 2010,.
** the Italian Biogas Association has written many Position Paper about #biogasdoneright concept. The Italian biogas industry is the third in the World, after China and Germany, and claims the co-existance among extraordinary Italian food productions and the energy derivated from AD.

Consorzio Italiano Biogas 14

The biogas *competitive advantage*

- Anaerobic digestion is not a bioenergy like all the others due to some factors
  - Efficient C energy conversion even on small scale
  - Multifeedstock
  - Nutrients recycling
  - Enhance livestock and agriculture sustainability
- All these "advantages/ (pluses)" make biogas the most "land efficient" bioenergy system available nowadays, comparable to solar/wind fuel pathways

Consorzio Italiano Biogas 15

Multifeedstock , Small Scale, Nutrients Cycling, less agriculture and livestock pollution

- AD is **Multifeedstock**:
  - We can use any organic substance available on any agro-ecological distribution area, to convert 70-80% of carbon fixed in chlorophyll photosynthesis into gas
  - avoiding MONO-CULTURES that, even though "no-food crops", are displacing food crops
  - biogas crops can improve farm land rotation and crop diversity
- AD is converting biomass to energy in an efficient way on **small scale** (>500.000 litre diesel equivalent), therefore
  - Applicable to any sized professional farm
  - We can use any biomass and avoid transporting watered (95-70%) biomasses over long distances
- **Nutrients cycling**
  - By means of the digestate, the undigested carbon and all nutrients (**N-P-K-micronutrients**) may be re-deployed on site, sustainably and efficiently, restoring organic fertilization in areas where there is no more livestock and improving soil quality and farm output
- With biogas we can dramatically reduce the **modern agricultural pollution in the fields and in the stables**

Consorzio Italiano Biogas 16

Biogas Double Cropping intensification

Strip tillage seeded Corn silage for the Stable
after winter rygrass for the digester (Federici Farm – Cremona)

Consorzio Italiano Biogas 17

Biogas crops diversification
Sulla (Hedysarum coronarium) silage

Pecorino Farm – Sicily

Traditional mediterranean Nitrogen fixing crop useful to avoid durum wheat monoculture and soil desertification.

Nowdays this crop is without market demand due to sicilian livestock industry decline . In the background ***Etna*** *Europe's tallest active volcano*

Consorzio Italiano Biogas 18

Pre-seeding umbelicale digestate fertilization instead fossil Urea

Artegiani Farm - Verona

Consorzio Italiano Biogas 19

Drip irrigated Corn after Triticale

Cazzola farm- Verona

Fertilized with **Renewable Ammonium Sulphate** made via digestate evaporation

✓Less watering
✓Less Nutrients
✓More nutrients vegetables intake
✓50% more yields
✓More predictable yields

Simply
less risky&costly
more sustainable corn farming

Consorzio Italiano Biogas 20

Rye grass digestate late winter fertilization

New Hollande T6.140 Biomethane powered tractor

Consorzio Italiano Biogas 21

The biogas land efficiency

- Biogas enables the processing of a technological pathway to biomass production
- taking up land currently allocated to food and feed production in an acceptable way
- The benchmark to measure the efficiency of bioenergy systems in farmland use is **land efficiency**,

- **i.e.**
  - *The quantity of primary energy obtainable from a hectare farmland used* ***in substitution*** *of previous food and feed crops*

Consorzio Italiano Biogas 22

The metrics: "land efficiency" formula

$$FCLR(ha) = \left(\frac{A-I}{C}\right) \times \frac{1}{P}$$

- Land requirements are therefore not only linked to productivity of first harvest crops,
- But are equally influenced by
  - Efficiency of technological and biological conversion systems
  - The availability of primary Energy coming from integration biomasses.

- **FCLR**: the requirements (ha) of first harvest land needed to produce biogas
- **A**: is the primary energy (MWh th) which has to be produced by first harvest crops
- **I**: is primary energy (MWh th) produced by **integration biomasses**, that is from biomasses, which do not require first harvest land for their production
- **C**: is the conversion factor that defines the quantity of primary energy obtainable per biomass ton in first harvest (MWh th /ton)
- **P**: is the quantity of biomass we can get from first crop harvest land (ton/ha)

The formula is freely drawn from Lynd e others"ENERGY MYTH THREE – HIGH LAND REQUIREMENTS AND AN UNFAVORABLE ENERGY BALANCE PRECLUDE BIOMASS ETHANOL FROM PLAYING A LARGE ROLE IN PROVIDING ENERGY SERVICES" 2007

Consorzio Italiano Biogas 23

The"I" factor for *advanced biofuel*

The "I" factor

- In the case of biogas the "I" factor is more conducive to land saving than "C" and "P" alone
- Integration biomasses are all those biomasses that do not require first harvest farmland and that
  - Currently do not represent income for farmers (by-products, second harvest crops, etc.)
  - May even be a cost (livestock effluents, etc.)
  - And which therefore integrate farm income without significantly impairing profit generating capacity in the food and feed sector.

The "Integration biomass"**

- Catch crops (double cropping) **after or before** cash crops (for digester in **bold**)
  - **TRITICALE** – soy
  - **RYGRASS** –corn
  - Wheat- **SORGHUM**
- **Nitrogen Fixing Crops** in yearly rotation with cereals for the food and feed market
  - **Trifolium**
  - **Rygrass**
  - **Sulla (Hedysarum coronarium)**
  - **Alfalfa**
- Perennial crops on marginal /set aside lands ,
- Biomass from grasslands
- Livestock effluents
- Agricultural and agro-industrial by products

***These indications refers to the Italian example. The biogas strenght is the ability to adapt to every kind of diet and agroecological conditions from temperate to arid climates*

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Land efficiency in North Italy
Only **Corn silage**

1 Milion Nmc Ch4 bio/year	ton FM/day	Yelds /ton/ha	FCLR Ha	MWh th /ha
FIRST CROP BIOMASSES				
Corn	21	55	141	72
Rape				
PARTIAL	21	55	141	72
INTEGRATION BIOMASSES				
Triticale (before soy)				
Sorghum (after grain wheat)				
Rygrass (before corn)				
Bovine manure				
Bovine manure				
Chicken manure				
PARTIAL	-	-	-	-
TOTAL	21		141	72

Land efficiency in North Italy
"Integration biomass"

1 Milion Nmc Ch4 bio/year	ton FM/day	Yelds /ton/ha	FCLR Ha	MWh th /ha
FIRST CROP BIOMASSES				
Corn	10	55	68	70
Sorghum				
PARTIAL	10	55	68	70
INTEGRATION BIOMASSES				
Triticale (before soy)	0			-
Sorghum (after grain wheat)	0			-
Rygrass (before corn)	0			-
Bovine manure	11		-	24
Bovine slurry	30		-	21
Chicken manure	10		-	30
PARTIAL	51		-	75
TOTAL	61		68	145

Biogas crops after or before food crops. No food/feed production reduction!

1 Milion Nmc Ch4 bio/year	ton FM/day	Yelds /ton/ha	FCLR Ha	MWh th /ha
FIRST CROP BIOMASSES				
Corn	3	55	21	72
Sorghum				
PARTIAL	3		21	72
INTEGRATION BIOMASSES				
Triticale (before soy)	11	40	-	192
Sorghum (after grain wheat)	9	40	-	132
Rygrass (before corn)	0	32	-	-
Bovine manure	8		-	59
Bovine slurry	9		-	21
Chicken manure	4			10
PARTIAL	41		-	413
TOTAL	44		21	485

Power to Gas

a way to double biogas land efficiency is C-CO2 with renewable H2 via methanation reaction

- In a 1 MWe biogas plant we use about 2.500 ton of C per year, About
  - 2.100 ton C is on the biogas
    - 1.100 as CH4
    - 1.000 ton as CO2
  - 400 ton C are in digestate

Energetische Nutzung der Biomasse: Thermochemische oder Anaerobe Konversion mit H_2

$$CH_{1,431}O_{0,661} + 1.946\ H_2 \longrightarrow CH_4 + 0.661\ H_2O$$

1 $kg_{Biomasse,\ trocken}$: 5,078 kWh + 0,163 kg_{H2}: 5,452 kWh (H_2 via Elektrolyse)

Reaktionsprodukt Methan: 9,267 kWh

→ 100 % C werden in Kraftstoff überführt.

M. Spechet "Power to Gas – zwischen Mytos und Wahrheit" July 2014

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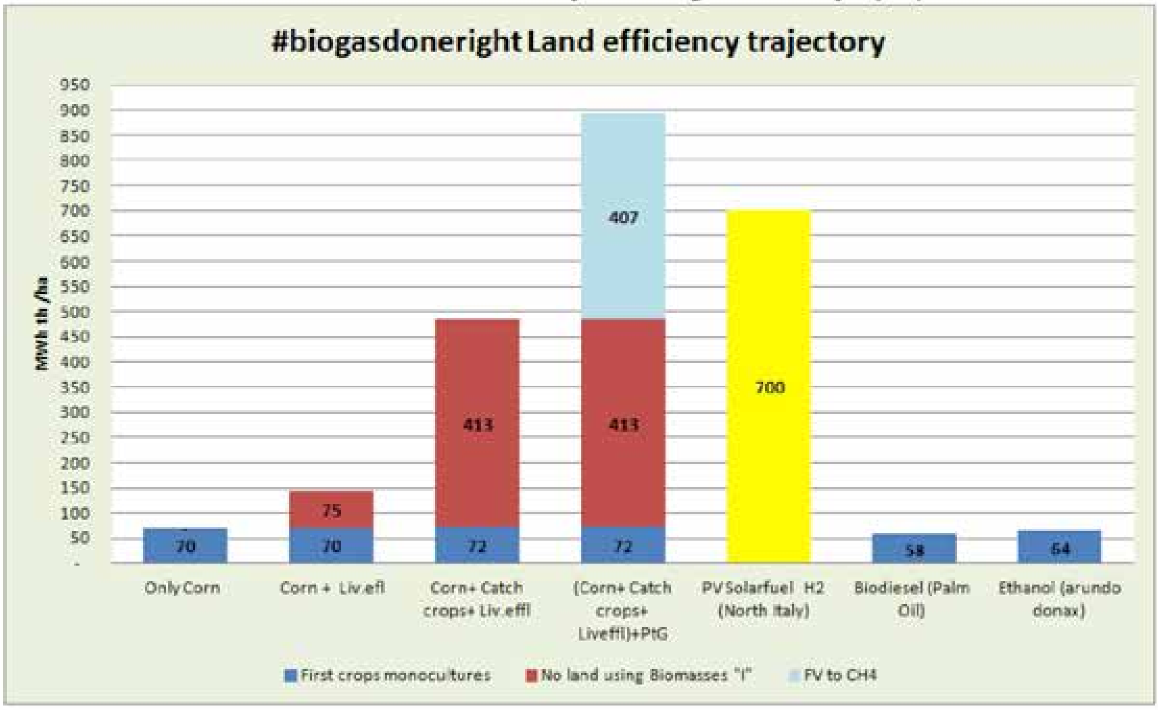
The #biogasdoneright "land efficiency" trajectory (1)



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The #biogasdoneright "land efficiency" trajectory (2)

- The biogasdoneright potential land efficiency is **from 5 to 10 times higher** than palm oil or cellulose ethanol obtained from food or no food **monocultures**
- This result is not related only to crop yields and AD conversion efficiency improvements,
- But moreover to
  - small scale plants and multifeedstock diet factors
  - that allow an extended use of integration biomasses and a progressive reduction in the need for first harvest land
- Big potential coming from sustainable biogas and solar H2 farming integration , moreover in the semiarid regions with high solar energy yields

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The #biogasdoneright an essential **technological infrastructure** for a sustainable and competitive agricultural business

- *The message that we would like to send to MEPs who have to decide on the reform of UE directive*
  - *we need **advanced biofuels**, i.e. biofuels , land and carbon efficient*
  - ***Biogasdoneright** is one of the best options that we have to produce C-renewable energy and spur investment targeting an ecological intensification of European Agriculture*
- *Like optical fibre network - it is a crucial infrastructure for the development of TLCs,*
  - *In agricultural businesses, anaerobic digestion is **an essential technological infrastructure** to trigger an agricultural (r) evolution on the farm,*
  - *useful to redesigning the use of soil, the nutrients cycle and to placing an agricultural business at the cutting-edge of greater sustainable production*

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Consorzio Italiano Biogas

invite you to follow the discussion
at **Milano-EXPO 2015**

“Feeding the planet.
Energy for the world”

*With **#biogasdoneright**, of course!*

Arrivederci

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BIOGASDONERIGHT

A case study to explain Biogasdoneright principles applied in the Po valley, northern Italy

2

The biogasdoneright concept

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Our claims

3

1. We can produce additional Carbon for the digesters without detract Carbon from Food/ Feed Markets and from agricultural residues devoted to service Soil fertility
2. We can do it by reducing business as usual agricultural emissions from fields and livestock activities
3. We can cycle all the nutrients entering in the digesters back to the fields by eliminating external purchases of fossil fertilizers and energy at the Farm
4. We can improve, in a continous and stable way, the organic input to soils by increasing fertility and C content
5. All these actions are able to improve farms activities cost competitivness, diversify cash flows and markets outlets , improving Bank credit merit, enabling the farmers for new investment for food , feed , energy output growth and soil carbon sequestration
6. We believe that #biogasdoneright is a technology platform that could be apply in every agroecological and social context to spur globally agricultural ecological intensification and degraded land revegetation
7. Through the digestate and residues carbon input increase, biogasdoneright enable Agricultural Soil as carbon sink to reverse Climate Change with a cost effective , doable and sustainable strategy ready to be applied.

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#biogasdoneright thesis (1)

4

- In a carbon constrained world, bioenergy is expected to act also for sequestering carbon and not only work on emission free energy like solar and wind (mitigation VS sequestration)
- But carbon needed for the production of biogas or whatever other biofuel, must be additional carbon to the one already produced for the food and feed, or from residues already used to improve soil fertility
- It must be additional carbon otherwise it will be «only» a renewable carbon already «photosynthetized», and then representing only avoided emission (Mitigation) and not extra carbon removed from the atmosphere (Sequestration).
- Additional carbon can be obtained in different ways:
  - Via NPP increase in current farmed land, either per increased yield of single harvest or per Ecological Agriculture Intensification
  - Or Via revegetation of degraded or under degradation land

The metrics : "land efficiency" formula

$$FCLR(ha) = \left(\frac{A-I}{C}\right) \times \frac{1}{P}$$

- Land requirements are therefore not only linked to productivity of first harvest crops,
- But are equally influenced by
  - Efficiency of technological and biological conversion systems
  - And by the availability of primary Energy coming from integration biomasses.

- FCLR: the requirements (HA) of first harvest land needed to produce biogas
- A: is the primary energy (MWh th) which has to be produced by first harvest crops
- I: is primary energy (MWh th) produced by **integration biomasses**, that is from biomasses, which do not require first harvest land for their production
- C: is the conversion factor that defines the quantity of primary energy obtainable per biomass ton in first harvest (MWh th /ton)
- P: is the quantity of biomass we can get from first crop harvest land (ton/ha)

The formula is freely drawn from Lynd e others "ENERGY MYTH THREE – HIGH LAND REQUIREMENTS AND AN UNFAVORABLE ENERGY BALANCE PRECLUDE BIOMASS ETHANOL FROM PLAYING A LARGE ROLE IN PROVIDING ENERGY SERVICES" 2007

This additional carbon production can be quantified through "Agricultural Land efficiency equation"
NB : Conversely to what people mainly think, the **I** factor in the equation has higher impact of the **P** factor on the final result (see Bozzetto talk "Biogas and sustainable farming " EBA congress Amsterdam 2014)

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#biogasdoneright thesis (2)

5

- Circa 40-50% of the carbon emitted in the atmosphere since the industrial revolution originates from loss of C in agricultural soils and in other biota
- Current agricultural and forest management account for 25-30% of CO2 emissions per year
- Additional carbon production cannot be achieved by conventional farming due to the CO2 emissions associated to it
- The intensification of NPP must be achieved via
  - Improved NUE & WUE of current agriculture
  - Lowering livestock emissions
  - Enlarging biodiversity in farmland
  - Improving Agricultural land efficiency
- More in detail , NPP intensification can be achieved via:
  - More soil coverage throughout the whole year
  - Increased crop rotation
  - Substitution of chemical fertilization with organic fertilization and nutrient recycling via digestate
  - NUE and WUE crops improvement via:
    - Fertirrigation with drip irrigation
    - Use of perennial nitrogen fixing crops (Alfalfa, Italian sainfoin,etc.) and CAM plants for Feed and Energy applications
    - Increase of rotation especially with nitrogen fixing crops

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Implementation of carbon negative systems (1)
Digestate & Soil Carbon Sequestration (SCS)

6

- 1 MWe biogas plant uses 2500 ton carbon per year (about 5.300 ton organic matter)
  - 1100 ton is carbon in the biogas as methane (CH_4)
  - 900 ton is carbon in the biogas as CO_2
  - 500 ton is undigested carbon in the digestate leftover
- The most of the C input is transformed biochemically into biogas in the digesters corresponds to the C in hemicellulose and easily accesible cellulose. Such C would have been readily oxidized in top soils anyway
- The C left over in the digestate correspond to the recalcitrant C of the biomass, thus mainly in the lignin and in cellulose adhesed to lignin . **Such C is the precursor of the humus.**
- This C (in the digestate)
  - As such
  - Or turned into **Biochar**
- Can contribute to the SCS bringing at the same time positive externalities such as increased fertility and increased C content of soils.
- The latter has positive effects on the Water Utilization Efficiency (WUE) and Nutrient Utilization Efficiency (NUE)
- Anyway the digestate in the biogas allows the application of organic fertilization on large scale
  - **Decoupling organic fertilization from the livestock growth**
  - Utilizing cover crops for energy uses, thus avoiding the nitrogen **famine** associated to the green mulching practices
  - Securing C supplies to the farm soils everywhere a digester is present

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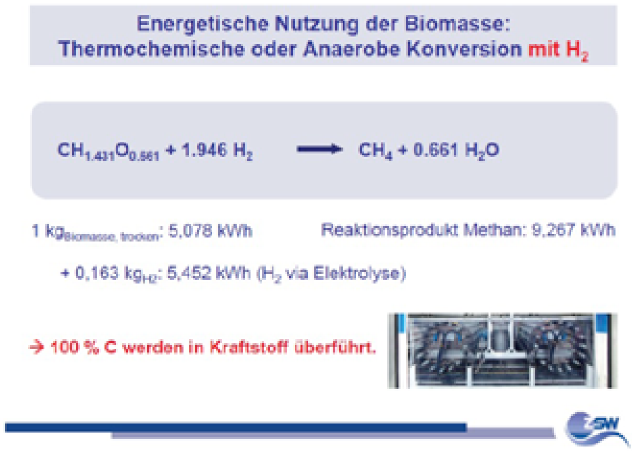
Implementation of carbon negative systems (2)
C of CO2 sequestration via Carbon Reuse

7

- In the mass balance of the biogas plant:
  1. **36% circa of the C in the biomass is in the CO2**
  2. 20% of the C in the biomass is in the digestate
  3. 44% of the C in the biomass is in the CH4
- The SCS potential of the biogasdoneright can profit from the **development of technologies able to reuse the CO2 in the biogas.**
- The current bottleneck is the price of **renewable H2** (needed in most of the processes)
- Power to Gas (PtG) is just one of the possibility to reuse the CO2 coupling it to renewable energy generation (solar/wind fuels)
- PHA biopolymers production , composites, etc. are others examples.



http://www.powertogas.info/fileadmin/user_upload/downloads/Vortraege/Konferenz_2014/140702_dena_Jahreskonferenz_PtG_Specht.pdf

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Biogasdoneright and soil carbon sequestration (**SCS**)

8

- AD due to its key advantages:
  - Efficient C conversion even at small scale (>500.000 liters diesel equivalent per year)
  - Multifeedstock,
  - Codigestion aptitude and ability to use watered biomass (till 2-3% dry matter content)
  - Flexible to match different enviroments/farms
- It is a **technological platform** able to:
  - Produce additional carbon without lowering food & feed sales at farm gate
  - Help to achieve a real ecological agriculture intensification
  - Implement organic fertilization at any desired scale
  - Sequestrate carbon at near to zero cost since the carbon storage via organic fertilization have to be paid back as much as possible by
    - an increased NPP (products)
    - and soil fertility (services)

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9

A case study

A farm in the northern italian Po valley, near Ferrara

It's only an example of "Silent Spring Revolution" that many many italian biogas producers are trying to do

Biogas feed in tariff is spuring a spontaneous ecological agricultural intensification as show in the next slides, naturally.

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Situation prior to the Biogas plant

10

- The farm, located in the Po valley, comprehends :
  - 320 Ha (three owners)
  - A stable for 150 milk cows, milk used for "squaccherone"cheese production
- In the last years , the farm was unprofitable, with old machineries and insufficient works days to employ the people available
  - The full time employed corresponded to 2,5 units
- Fertilization
  - Organic fertilization uses 2,5 k Ton of manure and 4 k Ton of slurry; manure is applied to 100 Ha; slurry to additional 50 Ha
  - 80% of crops was using chemical fertilizers
- The land devoted to stable is 50 Ha:
  - 20 Ha of Alfalfa
  - 30 Ha of corn silage
- The farm buys yearly:
  - 300 Ton of feed grains
  - 40 Ton of soy meal
  - This corresponds to 70 extra Ha requirement
- For the market sales are used 270 Ha yearly, mainly corn & wheat grain in rotation with few hectares of Soy bean
- Harvest yields (in a „low fertility" region) was
  - 6 Ton/Ha wheat
  - 8,5 Ton/Ha grain maize
  - 4,0 Ton/Ha soy bean in1st harvest

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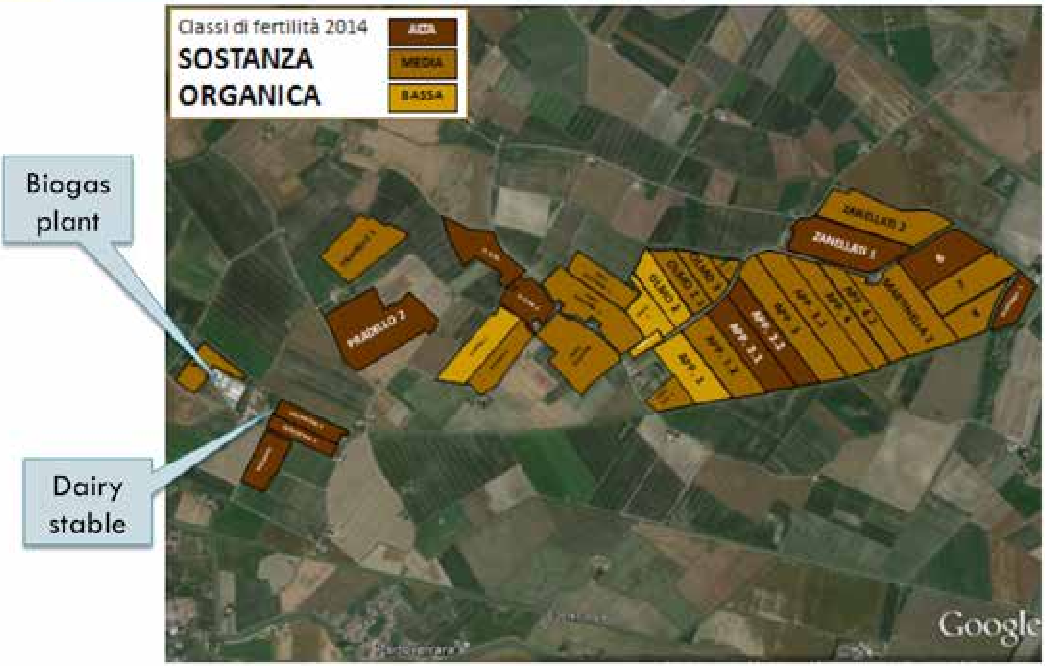
Situation of organic matter at the farm

11



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Organic content of soils at different locations of the farm

12

COD.	Campo	Sabbia %	Limo %	Argilla %	Classe tessitura	pH	Calcare %	Sost. Org. %	Azoto Tot. ‰	C/N	CSC meq/100g	P_2O_5 ppm	K_2O ppm
Q5434	GEPPA	17,5	52,0	30,5	FRANCO-LIMOSO-ARGILLOSA	7,8	7,1	2,18	1,56	8,01	22,50	44,4	[illegible]
Q5435	NOGAROLE	19,4	54,8	25,8	FRANCO-LIMOSA	7,7	6,6	2,21	1,59	8,06	[illegible]	60,2	535,3
Q5436	LAMBERTINA B	25,4	44,8	29,8	FRANCO-ARGILLOSA	7,7	7,0	2,62	1,91	[illegible]	23,10	93,2	735,4
Q5437	LAMBERTINA A	25,5	45,9	28,6	FRANCO-ARGILLOSA	7,7	8,2	2,93	2,04	8,33	23,10	121,8	753,6
Q5438	PRADELLO 1	20,8	51,6	27,5	FRANCO-ARGILLOSA	7,7	9,2	1,82	1,24	8,51	20,20	16,5	222,2
Q5439	PRADELLO 2	28,8	50,1	21,1	FRANCO-LIMOSA	7,6	9,1	2,13	1,48	8,36	17,60	18,3	261,0
Q5440	POVERA	28,3	47,6	24,0	FRANCA	7,8	9,1	1,95	1,40	8,06	18,70	24,3	233,5
Q5441	8	17,6	52,8	29,6	FRANCO-LIMOSO-ARGILLOSA	7,8	10,3	2,32	1,70	7,90	22,30	24,5	331,8
Q5443	MARTINELLA 1	15,0	53,0	32,1	FRANCO-LIMOSO-ARGILLOSA	7,8	9,3	2,55	1,82	8,14	24,10	27,3	428,6
Q5444	7	19,1	51,5	29,4	FRANCO-LIMOSO-ARGILLOSA	7,8	9,2	2,08	1,37	8,81	21,70	23,8	302,9
Q5445	6	21,8	47,4	30,8	FRANCO-ARGILLOSA	7,8	9,5	2,96	1,75	9,77	24,30	29,3	394,3
S074701	APP. 1	18,1	54,6	27,3	FRANCO-LIMOSO-ARGILLOSA	7,9	10,1	1,95	1,28	8,83	20,40	13,5	183,2
S074702	APP. 1-2	21,2	53,8	25,0	FRANCO-LIMOSA	7,9	10,0	1,76	1,07	9,55	18,80	16,5	239,1
S074703	OLMO 1-1	36,7	47,0	16,1	FRANCA	8,0	12,4	1,06	0,54	11,39	12,90	6,9	85,4
S074708	LA ROSA	25,3	52,5	22,2	FRANCO-LIMOSA	7,7	13,2	2,55	1,69	8,75	19,10	61,8	969,6
S074709	MARTINELLA 2	23,1	49,0	27,9	FRANCO-ARGILLOSA	8,0	9,5	1,85	1,21	8,66	20,50	18,1	244,4
S074710	APP. 4-2	7,9	51,0	41,1	ARGILLOSO-LIMOSA	7,9	5,9	2,20	1,67	7,66	28,00	18,1	245,5
S074711	OLMO BOL 4	26,1	50,7	23,2	FRANCO-LIMOSA	7,8	9,4	1,73	1,15	8,67	17,80	23,6	333,6
S074712	OLMO 2-1	13,4	53,7	32,8	FRANCO-LIMOSO-ARGILLOSA	7,9	7,9	2,05	1,36	8,73	23,40	16,5	243,2
S074713	OLMO 3-1	12,5	54,4	33,1	FRANCO-LIMOSO-ARGILLOSA	7,9	8,9	2,18	1,36	9,31	23,80	9,2	192,0
S074719	POVERA 2	18,3	54,6	27,1	FRANCO-LIMOSO-ARGILLOSA	7,9	10,5	2,01	1,31	8,90	20,40	38,7	385,7
S074720	OLMO BOLOGNESI 2	17,5	56,2	26,3	FRANCO-LIMOSA	7,9	9,3	1,94	1,21	9,28	19,80	20,8	234,5
S074721	OLMO 2	12,7	55,1	32,2	FRANCO-LIMOSO-ARGILLOSA	7,9	8,8	1,93	1,33	8,41	22,80	17,6	258,2
S074724	ZANELLATI 2	5,8	50,6	43,6	ARGILLOSO-LIMOSA	7,9	7,3	2,48	1,60	8,50	29,80	17,9	[illegible]
S074725	APP 2-2	14,4	50,5	35,1	FRANCO-LIMOSO-ARGILLOSA	7,8	8,7	3,17	1,96	9,37	[illegible]	28,4	367,8
S074726	OLMO BOL 3	28,9	48,2	22,9	FRANCA	7,8	10,8	1,63	1,04	9,12	17,50	22,2	340,9
S074727	OLMO 1	39,4	44,2	16,4	FRANCA	8,0	12,4	0,79	0,48	9,58	12,30	4,1	70,6
S074729	LA ROSA 2	20,8	55,2	24,0	FRANCO-LIMOSA	7,7	11,6	2,48	1,62	8,88	19,80	60,0	853,1
S074730	OLMO BOLOGNESI	17,1	54,8	28,1	FRANCO-LIMOSO-	7,9	8,5	2,03	1,31	8,98	21,00	21,5	214,6

Land closest to stable

Land furthermost from stable

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Construction of a biogas plant fed with 1st harvest «first crop»,corn silage i.e. only one crop monoculture (1)

13

- In 2012 a 1 MWe biogas plant was built
- Its required an investment of 6 million€
- The initial diet for the biogas plant was (fresh matter) :
  - 9 Ton manure and 10 Ton dairy slurry per day, coming from the stable
  - 42 Ton per day of corn silage from monoculture, following the "German biogas system" advice

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Construction of a biogas plant fed with 1st harvest «first crop»,corn silage i.e. only one crop monoculture (2)

14

In this way crop rotation was reduced compared to the situation prior to biogas, with no winter crops, no leguminous crops, with a focus on corn silage monoculture

No winter grains harvest means also no straw for the stable, thus adding costs

Production for the AD:

- Covers all the land area of the farm, including the one that before were used for cash crops to sale on the markets
- But wasn't sufficient: there was a need to purchase from 3rd parties corn silage corresponding to further 71 ha

Land ha	Prior biogas	Biogas
Wheat silage		0
Wheat grain	50	0
Nitrogen fixing Mix and triticale		0
Triticale		0
Corn silage for the Digester	30	30
Corn silage for the Stable		270
Corn grain	210	
Sorghum grain		
Sorghum silage	0	
Soy bean	10	
Alfalfa	20	20
Alfalfa (1st and 5th cut) for the digester		
OVERALL	320	320
	0	0
double crops	0	0
first crops	320	320
CROPS DESTINATION		
Stable	50	50
Digesters		270
Market	270	0

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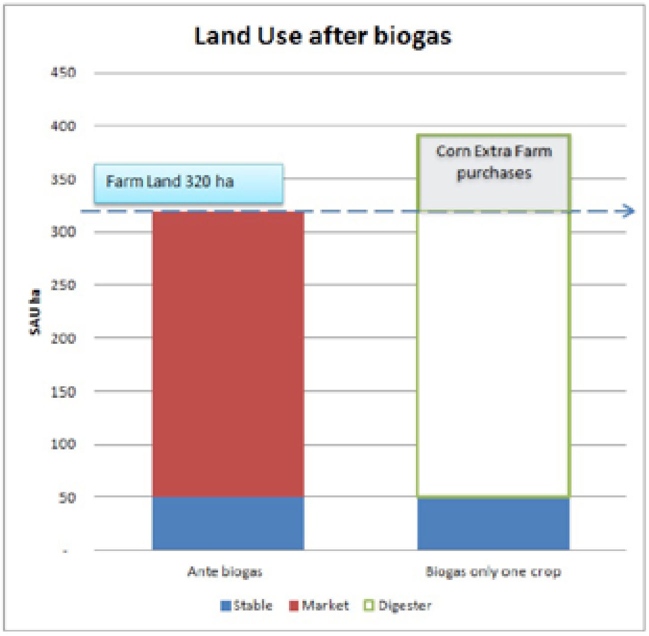
Land use after biogas with a monoculture diet (corn silage)

15



- The carbon used in the digesters is diverted reducing the C-forage sold on the market (wheat, corn and soy)
- More, the farm has to buy more extra farm corn silage to feed the digesters

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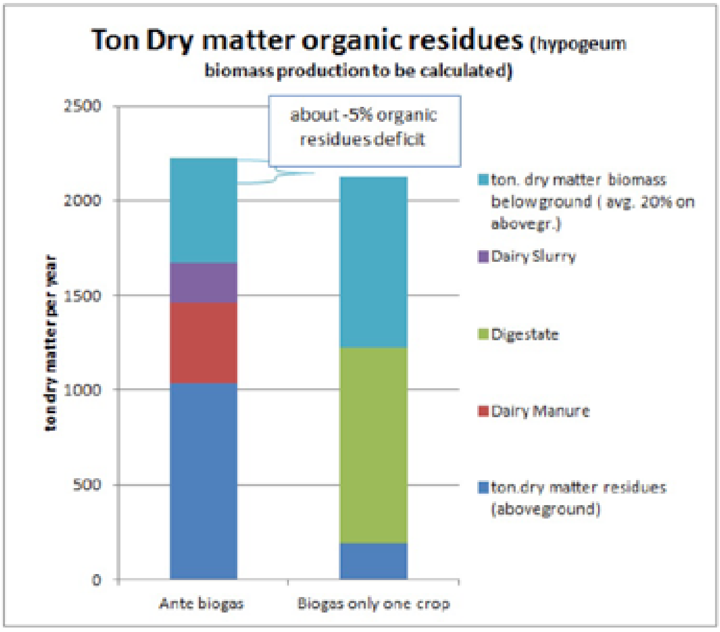
Organic matter mass balance

16



- The substitution of wheat/ corn grain and soy bean production, with corn silage monocropping, induce less left stover input coming back to the soil
- The farm has to buy wheat straw from neighbour farms
- The C-soil balance is on deficit (about -5% less carbon inputs)

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17

The biogasdoneright biomasses

A different approach to the production of renewable carbon

Double cropping and digestate soil fertility improvement

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Biogasdoneright

Pursuing an Ecological Agricultural Intensification

18

- After one year of management a new biogas feeding plan was developed
- The new plan aims at utilizing
  - 30 ton/day of livestock effluents (cows, chickens...)
  - The rest are catch crops silages harvested (at 50% milk line)
    - triticale and winter cereals
    - Maize and Sorghum
- Only 10 ha are only for the digesters, namely of Sorghum on farmland with low fertility and difficult management, in the farthest side of the Farm , difficult to irrigate too.

Digeters diet (ton fresh matter /day)

DIGESTER DIET	BIOGAS ONLY ONE CROP				BIOGASDONERIGHT			
	ton fm/day	Nmc/day	ton / year	FCLR	ton fm/day	Nmc/day	ton / year	FCLR
Wheat silage	0	0	0	0	3,7	814	1.350	0
Wheat grain	0	0	0	0	-	-	-	0
Nitrogen fixing Mix and triticale	0	0	0	0	5,8	1.093	2.100	0
Triticale	0	0	0	0	12,3	2.342	4.500	0
PARTIAL WINTER CROPS	**0**	**0**	**0**	**0**	**21,8**	**4249,315**	**7950**	**0**
Corn silage for the Stable	0	0			0,0	-		
Corn silage for the Digester	42	10.080	15.330	341	18,1	4.340	6.600	-
Corn grain	0	0	-	-	0,0	-	-	-
Sorghum grain	0	0	-	-	0,0	-	-	-
Sorghum silage	0	0	-	-	1,0	208	380	10
PARTIAL SUMMER CROPS	**42**	**10.080**	**15.330**	**341**	**19,1**	**4.548**	**6.980**	**10**
0			-				-	
0			-				-	
Chicken manure (eggs @10%DM)	0	0	0	0	10,0	1.200	3.650	-
Bovine manure	8	560	2920	0	9,6	768	3.504	-
Bovine slurry	12	420	4380	0	14,4	504	5.256	-
PARTIAL LIVESTOCK EFFLUENTS	**20**	**980**	**7300**	**0**	**34,0**	**2.472**	**12.410**	**0**
	62	11.060	22.630	341	74,9	11.269	27.340	10
Corn silage purchases				71				

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Biogasdoneright (1)

New land use plan: more crops in the rotations via catch crops double cropping strategy

19

- New land use plan foresee:
  - Double harvest for all the fields except the one planted with alfalfa perenennial crop
  - Intensification of soy in rotation as nitrogen fixing double crop for the market
  - Reintroduction of winter cereals, used for straw production for the stable and the grains are sold on the market
  - Maize, Sorghum & Soy in 2nd harvest are seed with no labour (in the future with strip tillage) to save time/water, and irrigation is provided by new ("water saving") irrigation systems behind big rolls systems
    - Drip irrigation
    - Pivot

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Biogasdoneright (2)

The new land use plan

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SAU ha	320	NEW LAND USE PLAN				FINAL USE				
Crops	Remarks	Winter crops	Mono crops	Summer Crops	Overall	Dairy Stable	Market	Partial	Digesters	FCLR for digesters
Silage Wheat	follow Corn silage center pivot and drip irrigated	30							30	
Corn Silage (stable)				30		30				
Wheat grain	follow Corn silage center pivot and drip irrigated	110					110			
Corn Silage (Digesters)				110					110	
Mix winter cereal/nitrogen fixing crops	corn grain with sprinkler irrigation	60							60	
Corn grain				60			60			
Triticale silage	sprinkler irrigation	100							100	
Sorghum Silage				10					10	10
Soy bean				90			90		0	
Sorghum grain				0					0	
Alfalfa			20			20			0	
Alfalfa (1st/5th cut) for digester			0						0	
OVERALL HECTARES		300	20	300	620	50	260	310	310	10

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Changes in the land use plan triggers a better use of digestate and spur sustainable farming practices

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Targets

- Elimination of chemical fertilizers using and improvement of the digestate application
- Planning of the digestate using is submitted to crops requirement and not at the aim to discard the slurry because the storage tanks are full as usually
- Keeping the soils moist and no compacted
- Reduction of seeding waiting time between first and second crop to optimize photo and thermo-period for the second crop growth
- Secure and increase crops yields avoiding soil compaction and improving organic fertility

Actions

- Tank digestate storage volume improvement
- Umbelicale digestate spreading avoiding slurry tanker to entry in the fields and compact the soil
- Strip tillage, no labour farming
- Drip fert-irrigation and Pivot fert-irrigation wherever we can
- Data monitoring (GPS, soil conditions, agroeco parameters control)

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Biogasdoneright effects

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Biogasdoneright effects (1)

First crop land requirement : from 370 ha to 10 ha

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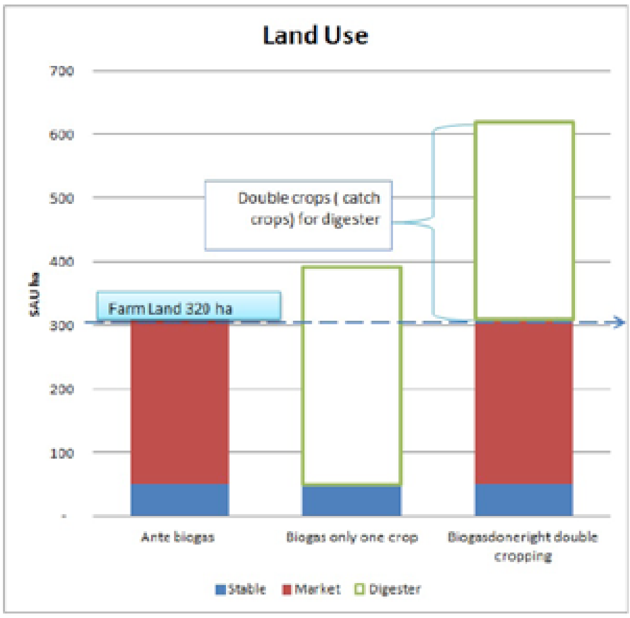
- The amount of land that produces for the markets is restored
- The biomasses needed for the biogas plant are not produced any more displacing the biomasses produced for the market



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Biogasdoneright effects (2)

Increased crop rotation, no chemical fertilizers, soil coverage long the whole year, increased agricultural residues production

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- *Differences to ante biogas plant situation*
  - ***Crop rotation is improved****, from 4 crops ante biogas to 7 crop, with nitrogen fixing crops of 110 ha per year (1/3 of the farmland, 4 times more the prior to biogas situation) and 20 ha of alfalfa*
  - *The fertilization needs are almost entirely covered by the* ***nutrient cycling via digestate***
  - ***Soil coverage*** *happens almost over the whole year allover the farm and not only over the alfalfa fields (20 ha over 320 ha ante biogas,* ***now 320 ha over 320 ha all year around!****)*
  - The straw needed for the stable is not anymore purchased ex-farm but the farm is again in the position to self-produce it for its own need and at the same time **increases the production of agricultural residues.**

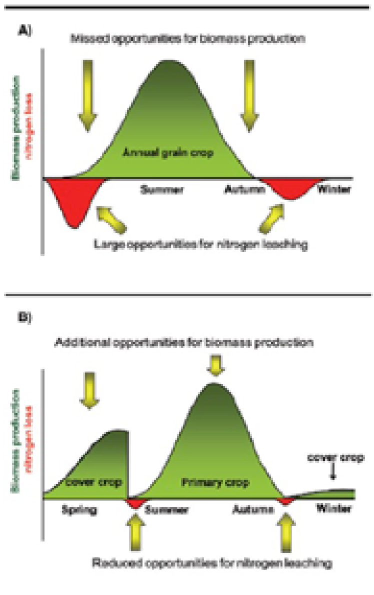

Fig. 1. Hypothesized representation of the seasonal dynamics of dry matter production and NO_3–N leaching (A) in an annual grain cropping system and (B) in a bioenergy double-cropping system.

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Biogasdoneright effects (3)

Higher production of agricultural residues

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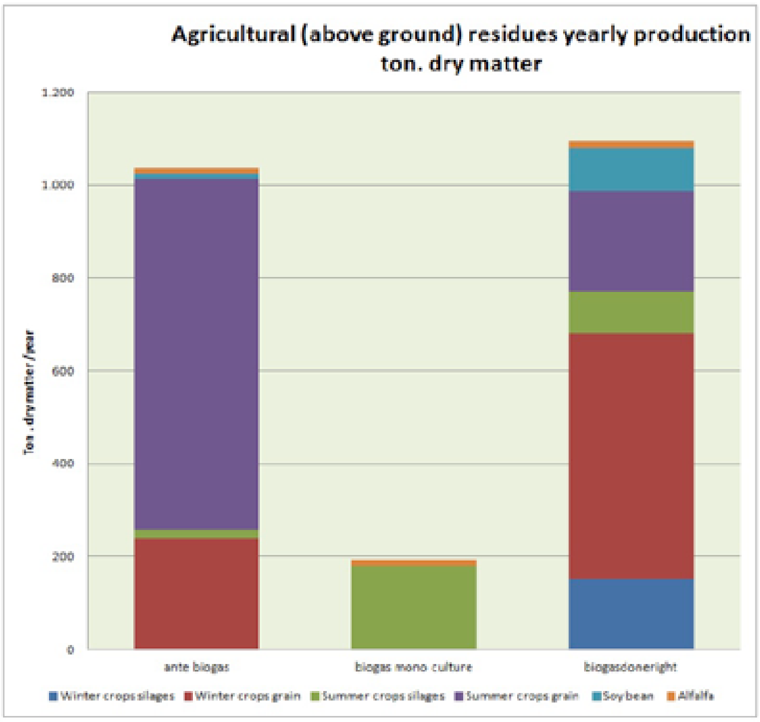
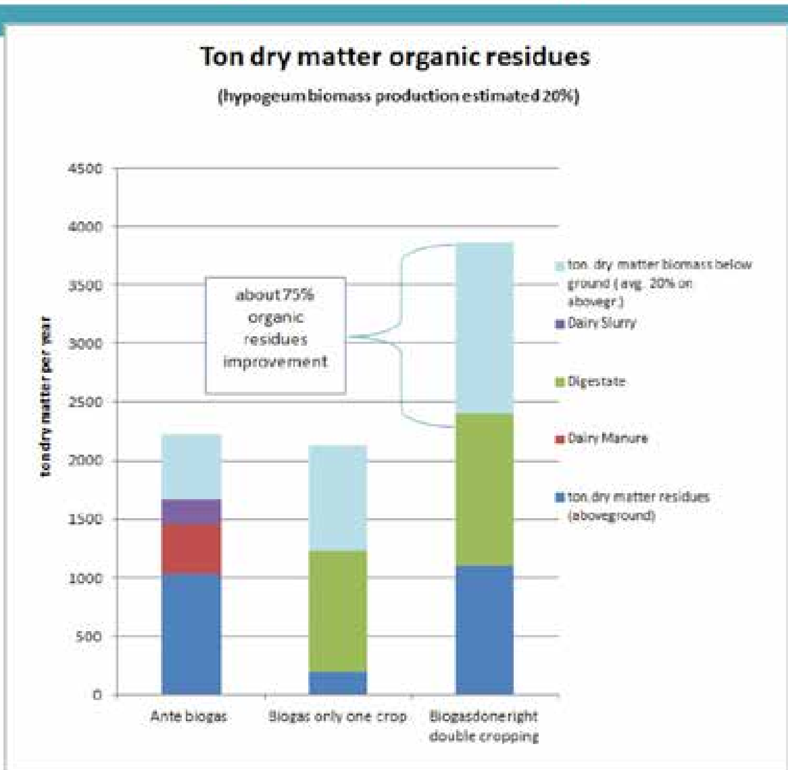


- Underground biomass balance is under review
- We expect a a non-negligible contribution to residues mass balance increase

Biogasdoneright effects (4)

>75% increase of organic fertilization compared to the ante biogas

26



Mass and nitrogen balance

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INPUT		ton/Day	ton/year	% on FM	N zoo kg/a	N veg kg/a	N tot kg/a
Silages		41	14.929	54,6%		52.311	52.311
Bovine Manure		10	3.504	12,8%	10.512		10.512
Chicken manure		10	3.650	13,4%	56.575		56.575
Bovine Slurry		14	5.256	19,2%	18.396		18.396
Other		-	-	0,0%			
OVERALL		**74,9**	**27.339**	**100,0%**	**85.483**	**52.311**	**137.794**
Biogas production		- 14,17	- 5.172				
	Nmc/year		*3.972.964*				
	Nmc/day		*10.885*				
	Nmc/h		*454*				
Digestate as is		**60,73**	**22.167**		85.483,0	52.310,7	137.793,7
Liquid digestate (@3-5% DM)		*48,58*	*17.733*				
Solide digestate (@20-25%DM)		*12,15*	*4.433*				

- 60% of Organic Nitrogen is mineralized in the digestate at N-NH3
- All P-K-S- micronutrients are recycled back in the digestate
- About 20% of carbon is back on the digestate

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Summary

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Biogasdoneright effects

Reduction of GHGs emissions from the agriculture sector and increases the organc matter of soils

29

- *Biogasdoneright at Ferrara farm*
  - it integrates with the farm productions (it kept the stable opened and keep unchanged the output for food & feed markets) due to its flexibility in being implemented
  - Keep the farm independent from fossil fertilizers purchase via the **digestate**
- Biogasdoneroght is also a bioenergy able to produce additional carbon & reduce GHG emissions at the same time
  - *Mitigating GHGs emission from farming and from livestock management*
  - *Increasing the harvest yield via an improvement of the digestate use.*
    - *As a matter of example at the Ferrara farm the yield increased of 30% in the last three years*
  - *Significantly increasing the carbon content of soils, especially where today is below the 1% and where no farmyard manure is available*
  - *Decoupling the organic fertilization from the an unlimited development of livestock industry,*
    - *especially in a momemnt where the Italian milk market prices are too low to justify any investment in this direction*

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A summary of the results

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Item	Ante	Biogasdoneright	Var.
SOCIAL			
Job units	2,5	5,5	3
% variation			120%
Market diversification	(-)	(+)	
Food commodities production cost	(+)	(-)	
Cash flow	(-)	(+)	
Capital atractiviness	(-)	(+)	
New investment .000€		€ 6.000	€ 6.000
Turnover €	€ 558.040,00	€ 2.716.925,89	€ 2.158.889,89
			387%
LAND USE			
Nitrogen fixing crops (ha)	30	110	80
Biodiversity (N. of Crops in rotation)	4	7	3
Yearly crop cover time (month)	5	11	6
Land managed	320	320	0
JK ha (land diverted from Food/Feed markets)	0	10	10
Intensification (ha crops harvested)	320	620	300
% variation			94%
OUTPUT			
Cereal and soy bean for the market Ton	1.960	1.820	- 140
% variation			-7%
Milk at the market Ton	1.460	1.460	0%
Nmc Biomethane/year		2.089.260	
Organic input to the fields ton dry tons/year	1.669	2.405	736
			44%
"Fossil "fertilizers purchases ton	2.400	384	- 2.016
			-84%

N.B.

Often I'm been challlenged that second harvest or more nitrogen fixing crops in the rotations could occur also without biogas production

May be with some subsidees…

This argument is brought by people that are not farmers or at least that haven't any experience about the money coming from agricultural markets.

The today clustering of livestock production in some areas dropped the demand for nitrogen fixing plants silage where no livestock is bred

Only the possibility to make silage and no grain allow the NPP Ferrara intensification . And the milk price unable us to apply this land use strategy without biogas turnovers.

The additional demand arising from the biogas plant is whart drive the ecological agricultural intensification

A conscious and effective use of digestate help to make the difference

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Ferrara Land Efficiency review

From 320 ha to 10 ha of 1° harvest land,
circa 2.100 MWh th/ha, 35 times more the best Palm Oil land efficiency

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The FCLR (first crop land requirement, land subtracted from Food & Feed production) it corresponds to 10 ha of Sorghum silage, on recalcitrant soils thatr are difficult to irrigate

The 80-85% comes from livestock effluent (cows or chickens) and from winter harvest or maize in second harvest. It isworth to mention that second harvest or winter harvest increased of 30% in the last years due to the digestate effects

$$FCLR(ha) = \left(\frac{A-I}{C}\right) \times \frac{1}{P}$$

20-15% of the efficiency comes from an improved yield of biogas formation due to a better diet regarding the NDF/ADF ratio of feedstocks, more starchy inputs etc.
In the following slides the profile of the organic digestable matter Consumption trend

In this case is first harvest Sorghum and the increase in yield plays a negligeable effect

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Biogas biotech conversion improvement (A)

(10.500 Nmc biogas/day @53% Ch4)

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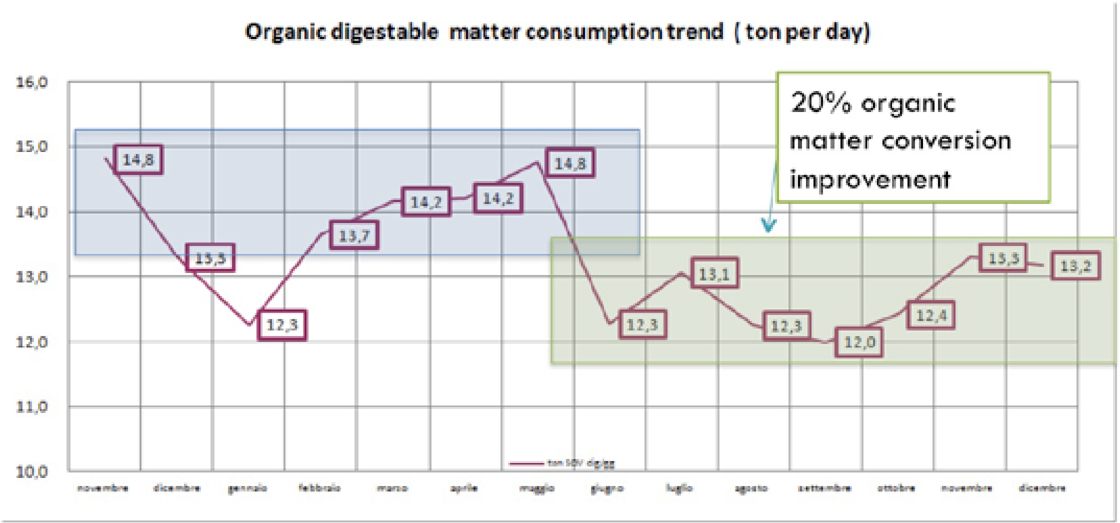

Biogas biotech has a lot of room to improve it's efficiency : micronutrients, hydrolitic enzymes, C-CH4 conversion improvers, nitrogen biomass in continous removal, etc.

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General remarks

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The efficiency of the biogasdoneright

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In reducing GHG emission in farming and about carbon sequestering, biomasses could be divided in:

A. Biomasses that produce **additional carbon**, that means carbon NOT produced at farmland previously used for food & feed or to enhance soil fertility
B. **Carbon from other bioms,** that is carbon NOT produced at the farm or that would be anyway used at the farm (e.g. purchased manure)
C. Carbon that **replaces food & feed**, when with a monocolture we feed the AD plant instead to sell it in the food markets.

Biofuelsdoneright targets:

-->A. & B. need to increase, C. need to decrease

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Biomasses for the biogasdoneright

A new feeding plant for the biogas plant that rely almost entirely on integration biomasses (thus additional carbon) was prepared for Ferrara biogas plant

35

	BIOGAS from mono cultures			BIOGASDONERIGHT		
ton dry matter /day	Additional C	C from others bioma	C substitutional of food and feed	Additional C	C from others bioma	C substitutional of food and feed
Silage wheat				1,2		
Wheat grain				-		
Mix winter cereal/nitrogen fixing crops				1,7		
Triticale				3,9		
Partial winter crops	-	-	-	6,9	-	-
Corn silage for stable				-		
Corn silage for digesters			14,3	6,1		
Corn grain				-		
Sorghum grain				-		
Soghum silage						0,4
Partial summer crops	-	-	14,3	6,1	-	0,4
Chicken manure		-			3,1	
Bovine manure		1,6			1,9	
Bovine slurries		0,4			0,6	
Partial livestock	-	2,0	-	-	5,6	-
OVERALL TON DRY MATTER DAY	-	2,0	14,3	13,0	5,6	0,4
			16,2			19,0
Digestable matter ton /day			13,0			14,5

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The biomasses for advanced biofuels

Overcoming the "food" vs "no-food" crops useless lexicon

36

	ADVANCED BIOFUEL (so called second generation biofuel)		FIRST GENERATION BIOFUEL
Biomass	Additional C	C from others bioma	C substitutional of food and feed
Annual mono crops on already cultivated agricultural land (food or no food)			
Catch crops (double cropping) after or before cash crops			
Nitrogen Fixing Crops in yearly rotation with cereals for the food and feed market			
Perennial grasses			
Perennial grass and nitrogen fixing crops on marginal /set aside or degraded lands			
Livestock effluents			
Agricultural by products on the condition that the soil carbon fertility is at least maintained			
Industrial by products			
Organic waste			
Aquatic plants and algae growth on no cultivated lands			
Renewable liquid and gaseous fuels of non biological origin			

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Biogasdoneright : a crucial tool to turn the agriculture into a carbon negative industry worldwide

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- *Biogasdoneright it is a technological platform adapted to different environmental and social area*
- *and it is able to achieve an **ecological agricultural intensification and waste land revegetation.***
  - *Enhancing the NPP producing additional carbon*
    - *To be used in the biogas production*
    - *To produce digestate thuis allowong organic farming even without livestock*
  - *Recycling nutrients locally thus making the farm indepoendent from chemical fertilizers*
  - *Bring innovation ion agriculture and allow the increase in NPP without increasing the GHGs emissions*

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Soil as carbon sink

How to recover soils under degradation or desertification and how to increase the organic fraction of current farmland

38

- *Farmland is a low-cost, distributed carbon sink with no access restriction and that is able to store more than 1 Gton of C yearly*
- *Carbon can be stored long term in soils if some agricultural practices are in place (nitrogen fertilization, green munching, covered soils, crop rotation with nitrogen fixing plants, no tillage...)*
- *These practices are anyway useful to increase soil fertility and to mitigate the environmental impact of conventiona agriculture.*
- ***But to increase the organic content of soils at the scale requested by climate change it is crucial the production of additional carbon to the one already produced for Food & Feed and to sequestrate this additional carbon input in the soils to slow down CO2 growht in the atmosphere***
  - *The organic farming experiece deomnstrated that with a constant input of organic carbon in the soils it is possible to sequestate carbon in them in a long term/stable way until reaching a plateau (soil saturation).*
  - *Considering the amount of abandoned or under degradation farmland on global level and the quantity of carbon that can be stored in soils there is more than enough room to outoperfomr the target of 1 Gton of carbon per year seqzestrated from the atmosphere.*
- *The organic Carbon can be stored long term in soils despite the well known oxidative (leaching and erosion) mechanisms, **if its administration is constant***
- ***Biogasdoneright strategy allows this.***

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"Soil is a carbon sink diffused and accessible to everyone, we cannot neglecting it! " R. Lal

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- *"The potential of Soil Organic Carbon (SOC) sequestration is finite in magnitude and duration.*
- *It is a short-term strategy to mitigating anthropogenic enrichment of atmospheric CO2.*
- *The annual SOC sequestration potential is only about 1,2 Pg C/year.*
- *The atmospheric concentration of CO2 at the observed rate of 1990 (3.2 Pg C/year) will continue to increase at the rate of 2.0–2.6 Pg C/year even with soil C sequestration.*
- *Thus, a long-term solution lies in developing alternatives to fossil fuel.* ***Yet, SOC sequestration buys us time during which alternatives to fossil fuel are developed and implemented.***
- *It is a bridge to the future. It also leads to improvement in soil quality.*
- *Soil C sequestration is something that we cannot afford to ignore"*

Rattan Lal

Director of Carbon Management and Sequestration Center

Ohio State University

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Biogasdoneright and Soil Carbon Sequestration
Many Scientists comes to speak about

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http://www.sciencedirect.com/science/article/pii/S2211464514000864

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Back up slides

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2015 (1) Land use situation in Ferrara

42

- Current situation:
  - In 2015 the land used for feeding the biogas plant in first harvest are 170 ha
  - Investment in fertirrigation infrastructure has not been made yet due to the extreme low price of agricultural commodities at the moment
  - Machines for strip tillage seeding and minimum soil labour have not been purchased yet for the same reasons has above
  - The use of chicken farm manure has not been authorized at the farm (beurocracy issues), whereas other biogas plant can already use it until 20 ton/day
  - In 2016 if the agricultural commodities prices will raise significant investment in agricultural machinery will be done and the land use planned will be achieved

Corn CBOT prices (2015 Jan 31st)

Soy CBOT prices (2015 Jan 31st)

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2015 (2) Fertilization in Ferrara

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- In the 2014 a research program to monitor the organic content of the fields was started
- 20% of the digestate is still distributed in summer as less usefull fertilization before spring seeding
- A tanker for digestate burying was bought and umbilical system for its burying will be bought soon
- A tractor suitable for conservative agriculture and with GPS will be bought
- A pivot irrigation system will be bought and fertirrigation will be implemented
- A system for the filtration of liquid digestate fraction need to be optimized (less 150 microns)
- In 2015 is forecasted the purchase of 50-70kg of complex nitrogen fertilizers, about 90% less than previous digestate biogas plant availability
- We hope in the future to start selling some organic and renewable fertilizers at the neighbours farmers

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Biogas Double Cropping intensification

Strip tillage seeded Corn silage for the Stable after winter rygrass for the digester (Federici Farm – Cremona)

Consorzio Italiano Biogas

Pre-seeding umbelicale digestate fertilization instead fossil Urea

Artegiani Farm - Verona

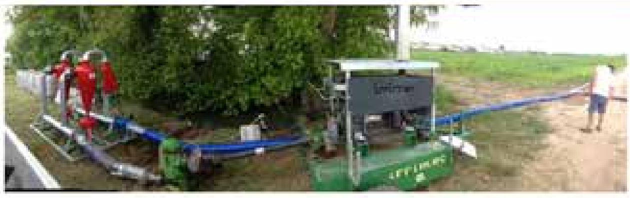
Consorzio Italiano Biogas

Drip irrigated Corn after Triticale

Cazzola farm- Verona

Fertilized with **Renewable Ammonium Sulphate** made by digestate evaporation

Experiments are in progress to try to utilize liquid 150microns filtred digestate



- Less watering
- Less Nutrients
- More nutrients vegetables intake
- 50% more yields
- More predictable yields

Simply
less riskly&costly
more sustainable corn farming

Consorzio Italiano Biogas

Digestate spreading solutions

47

http://www.digestatesolutions.co.uk/accurate-umbilical-slurry-spreading.html

Maschio Gaspardo Italy

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Rye grass digestate late winter fertilization

New Hollande T6.140 Biomethane powered tractor

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49

February Wheat grain iquid digestate fertilization

May –June Corn liquid digestate fertilization

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BIOGASDONERIGHT

A case study to explain Biogasdoneright principles applied at Enna Farm in Sicily

Ante Biogas situation

2

- Durum wheat is the main cash crop component in the rotation
- Sulla (Italian Sainfoin) is a nitrogen fixing crop adapted to mediterranean climate. Its demand is droping due to the decrease of the livestock industry in Sicily
- Italian Sainfoin in rotation is a key element to avoid protein content decrease in Durum Wheat when no rotation is in place
- Farmland is silty loamy on the hillside and clay loamy at the valley floor. The organic content is around 1% by average with consistent desertification process in place
- The economic profitability of the farm is very low and without the Common Agricultural Policy (PAC) subsidies it could barely survive

Farm Land for row crops and forages	550	ha	
Land use			
wheat durum	250	ha	50%
Sulla Sain fain	100	ha	18%
bare soil	200	ha	36%
Grain Sorghum	0	ha	0%
overall	550		

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3

Deployment of the Biogasdoneright

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Feeding diet for a 870 Nmc/h of raw biogas to biomethane project

4

Biogas feed plan	BIOGASDONERIGHT				
	ton as such/day	*Nmc*	*ton /year*	*FCLR*	*Ton DM/day*
Bran and broken wheat	0,1	55	37		0,09
Sorghum	23,0	4.600	8.395		8,05
Opuntia	50,0	4.000	18.250		6,00
Italian Sainfoin	26,2	4.192	9.563		7,86
Exhausted destoned olive cake	20,0	3.000	7.300		4,40
Citrus ssp. Pulp	40,0	4.400	14.600		6,00
Grapes marc	1,0	100	365		0,18
Livestock effluent	20,0	500	7.300		0,80
	180,3	20.847,0	65.810	100	33,38
MW eq	1,9	**869**			
Nmc BioCH4 /year	4.032.852				

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Biogasdoneright

A new crop planning that pursues an *ecological agricultural intensification*

5

- Set aside is not any more needed, a yearly rotation of cereals with Italian Sainfoin is in place thus the whole land is constantly cultivated and no bare soil is foresee
- Sorghum in second harvest after Italian Sainfoin, supported by drip irrigation
- Fodder and forage Opuntia as perennial crop
- The farmland subtracted to the market corrispond to 100 Ha, thus -30% compared to the ante biogas situation

Farmland (ha)	550									
		New crop plan				Use of soil				
Crops	NOTES	WINTER	Single harvest	Summer	TOTAL	Stable	Market	Partial	AD	fclr for digestor
Durum wheat	only for the market		250				250			
Italian Sainfoin	only for the digester to support C/N ratio	250							250	
Opuntia	catus for forage		50				0		50	50
Sorghum, grain in 1st harvest		0		0			0		0	
Sorghum Silage 2nd harvest	drip irrigated			250					250	250
Set aside	no more bare land									-200
TOTAL		250	300	250	800	0	250	250	550	100
			0						ha/1M Nmc	25

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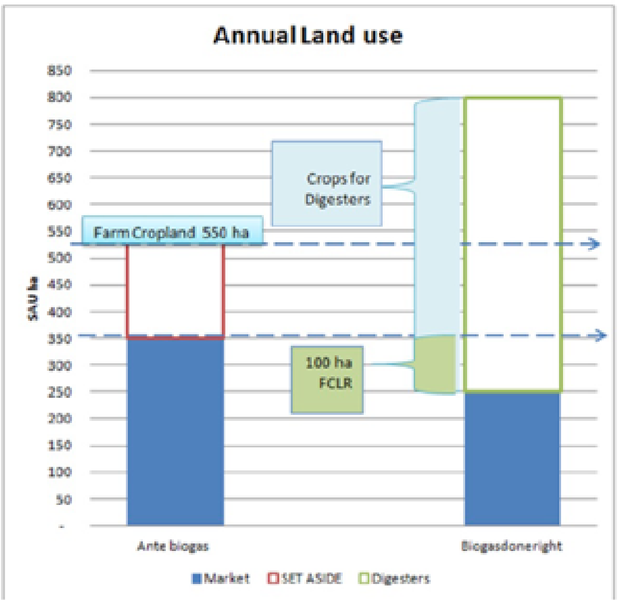
Biogasdoneright effects

First harvest utilization

6

- Set aside is removed when not functional to the mantenance of organic matter in the soil
- The plant leftovers at the field site are all buried
- Only 100 ha (30% of the farm surface) of first harvest are not allocated to the market and the silages are used for the biogas plant



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Biogasdoneright biomasses

7

In view of a harvest reduction for the market, a production of 4M Nm3 of BioCH4 is obtained

Production for the market (ton DM)	ante biogas	Biogasdoneright
Durum wheat	750	750
Italian Sainfoin	600	0
Opuntia	0	0
Sorghum grain 1st harvest	25	0
Sorghum silage 2nd harvest	0	0
Total ton for market	1.375	750
Increase in year production		-45%
Nm3 BioCH4 per year	0	4.046.374

It must be noticed that due to the livestock industry crisis in Sicily the demand for feed and forages like Italian Sainfoin is starkly decreasing

Raise in additional carbon production and valorization of carbon that today correspond to potential source of CO2 emission outside of the farm is achieved via biogas

	Biogasdoneright		
ton DM/day	*Additional Carbon*	*Carbon from other Bioma*	*Food or feed substitution carbon*
Bran and broken Wheat	0,1		
Opuntia	3,8		2,2
Sorghum	3,5		2
Italian Sainfoin	6,3		
Exhausted destoned olive cake		4,8	
Citrus ssp. pulp		7,6	
Grapes marc		0,2	
Livestock effluents		0,6	
Total	13,7	13,2	4,2
	44%	42%	14%
			31,1

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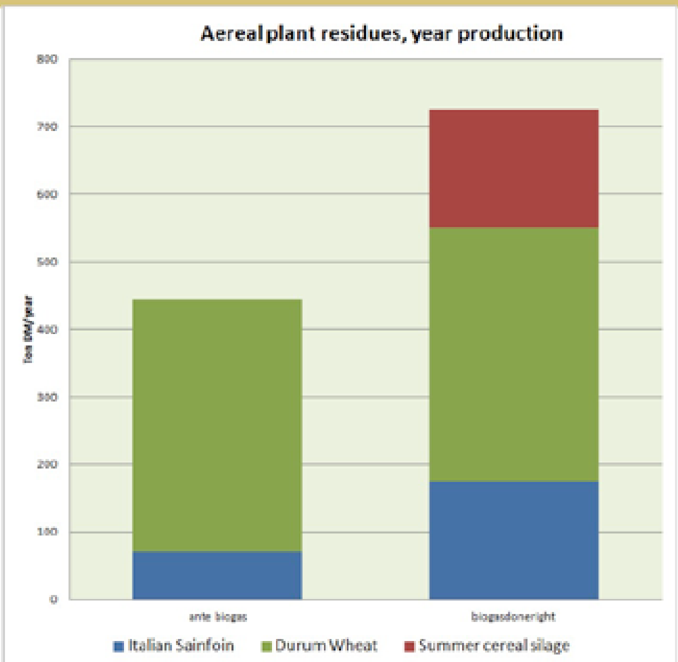
Biogasdoneright effects
More carbon residues for the soil

8

- A raise in harvests triggers a 50% raise in the green munching compared to the ante biogas situation, from crops residues



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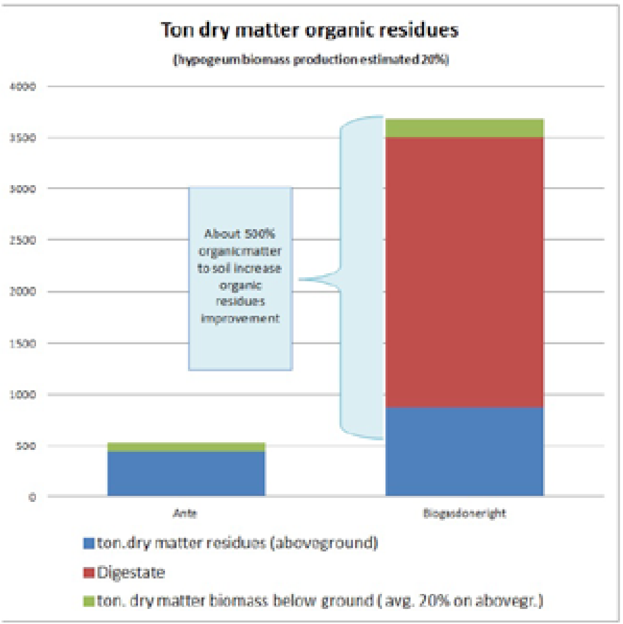
Biogasdoneright in Sicily is a terrific key tool to recover soil under desertification process

9

- The reduction of the food carbon is set off by:
  - Production of additional carbon for the biogas plant
  - The return of nutrients to the soil for all the crops, thus making the farm potentially independent from fossil fertilizers
  - The possibility to return organic matter to the soil is five fold higher compared to the situation ante biogas



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10

The biogasdoneright biomass in mediterranean regions

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Biogasdoneright biomass in semiarid areas
Opuntia

11

- At the current moment Opuntia is used in Sicily as arboriculture to obtain the prickly pear (fruit) as product
- Short planting distance of Forage Opuntia with drip irrigation & Organic fertilization is the main novelty in the crop rotation plan

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Opuntia foraggiera
(Prof. Paolo Inglese, Univ. Palermo, FAO Cactus Net Coordinator)

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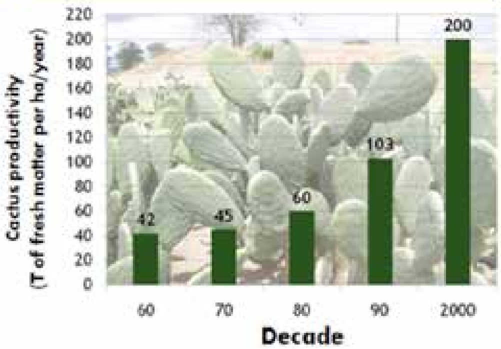
Increment of cactus productivity in experimental areas of NE Brazil in the last 50 years



With just a bit of water...

- Spacing 2 m x 0.1 m
- 5 L m^{-1} $week^{-1}$ (or 2.5 mm/wk)
- In situ water catchment
- Drip irrigation (C3S1 water)
- 23 T DM ha^{-1} Yr^{-1}
- 0.1 ha is enough to sustain two cows during 180 d with 50% of cactus in the diet

Lima et al., 2013 (to be presented in this meeting)

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CAM metabolism and WUE

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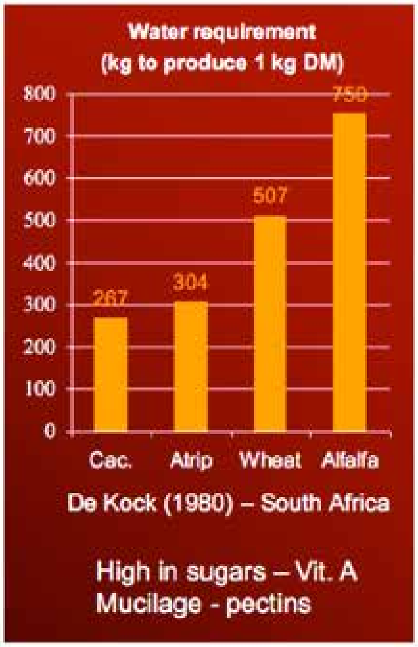
Photosyntetic cycle	WUE (kg H_2O/kg dm)
C_3	400-1000
C_4	250-500
CAM	**125-150**



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Biogasdoneright biomass in semiarid areas
Italian Sainfoin

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Biogasdoneright biomass in semiarid areas

Sorgo with drip irrigation

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Biogasdoneright biomass in semiarid areas

Waste food

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Waste orange peel

Waste oil mill

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The AD as tool to mitigate pollution and improve mediterranean agriculture competitiveness

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More competitive Farms

- Biogasdoneright concept is a meangifull tool to improve farm competitivity in mediterranean region
  - By diversifying market outlet
  - Reducing cost waste agro-food industry disposal
  - Reducing fertilization costs
  - And energy farm gate costs

More carbon in the Soil

- Biogasdoneright in semiarid regions, with soil in desertification progress, is able to enhance soil fertility
  - Via digestate and residues input to the soil increase
  - And improved crop rotation
  - And no bared soil land use

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