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Biogasdoneright™: An innovative new system is commercialized in Italy

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A group of over 600 Italian farmers organized as the Italian Biogas Consortium are redesigning their own farming systems to produce food and bioenergy in a nationwide farm-level movement called *Biogasdoneright*™. This Feature demonstrates how it is possible to simultaneously increase the economic viability and stability of agriculture by reducing farm input costs and enabling farmers to produce food and fuel more sustainably. © 2016 Society of Chemical Industry and John Wiley & Sons, Ltd

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Human beings obviously require food. Approximately 2000 kcal of food energy per capita per day and about 50 grams of protein per capita per day are the essential macronutrients. Thus the seven billion people on this planet need approximately 5100 trillion kcal per year and approximately 130 million tonnes of protein annually. Four major commercial crops (rice, wheat, corn (maize), and soybeans) alone provide about 8200 trillion kcal per year and 240 million tonnes of protein per year. This does not take into account the calories and protein provided by potatoes, manioc, sorghum, sugarbeets, sugarcane, canola, and many other crops. Thus we produce basic food crops far in excess of human needs.

Where does the rest of the food go? Some is lost between the field and the consumer, and some food is wasted at the table, but most human use of land is actually to produce animal feed. Large fractions of our grain and oilseed crops are used to feed animals. By far the biggest human use of land is pasture, all of which is for animal feed production.

Thus we use the term 'food/feed production' to highlight this crucial fact. Our dietary choices, not our essential nutritional requirements, govern humankind's land-use patterns. We mostly use land to feed animals, and then we consume the meat, milk, eggs, and cheese that the animals produce.

Human beings also require the many services that energy provides. Over the last few centuries we have consumed vast quantities of fossil energy. However, the wealth produced has been unevenly distributed around the world.

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Fossil energy is not renewable, thus the wealth produced by fossil energy use cannot be sustained long term.

Thus we require renewable, low carbon energy if we are to enjoy sustainable, long-term prosperity. Bioenergy can provide the desired renewable, low carbon energy services. In fact, for some critical energy services such as aviation, long-haul trucking, and ocean shipping, only high energy density liquid fuels are adequate. As a result, the consensus view of five independent analyses is that approximately 25% of total energy services must be provided by bioenergy.[1] The average amount of bioenergy required in these scenarios is very large, about 130 exajoules of primary energy per year. The inherent geographically distributed nature of bioenergy also helps ensure that the wealth derived from bioenergy production and use will be more equitably distributed than is the case with current fossil fuel use. Properly produced and used, bioenergy can be sustainable.

Why is bioenergy controversial?

The key reason for the controversy surrounding bioenergy is probably the perceived conflict with food production. Another reason is that current agricultural practices often contribute to environmental problems including deforestation, loss of biodiversity, and surface and groundwater contamination. For example, agriculture itself generates about 12% of global greenhouse gas (GHG) emissions.[2]

At a minimum, bioenergy must not interfere with food production and it must not worsen environmental problems. Preferably, we want bioenergy production to enhance food production potential and also to provide significant environmental benefits.

Thus we endorse the comments of Food and Agriculture Organization (FAO) Director-General da Silva who notes that:

> *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. There is no question that food comes first.* […] *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 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.*
>
> *Today we are better positioned to better evaluate the opportunities and risks of biofuel production and to use it when it pays off socially, environmentally and economically.*[3]

As Director-General da Silva states, we need to use bioenergy when it 'pays off socially, environmentally and economically'; in other words, when it is sustainable.

How can we have sustainable, large-scale bioenergy production?

We envision three primary avenues for sustainable, large-scale bioenergy production.

1. Woody bioenergy crops – the use of wood pellets

The use of wood pellets for fuel is growing rapidly, particularly in Europe. The existence of supply chains and infrastructure caused Europe to import wood pellets from the southeastern United States and even from western Canada rather than from Brazil, where the cost of growing wood is lower but the lack of ports and other infrastructure hinders exports. Supply chains matter greatly for large-scale bioenergy production.

2. Marginal (non-food) lands

'Marginality' is primarily an economic question. That question is: 'Can the farmer/land manager use the land to grow crops for which the revenue is higher than the costs?' Producing bioenergy and/or environmental services may render land that is uneconomical for food production sufficiently profitable to change marginal land into useful land. For example, perennial grasses planted on poor soils or sloping terrains may fix carbon in the soil and reduce erosion while still harvesting the grasses for animal feed and bioenergy production. Arid lands unsuitable for food crop production can be planted with low water use plants to provide animal forages and bioenergy.

Farmers must be motivated to manage these marginal lands if such lands are to provide food/feed and also energy services. Unfortunately, the needs of farmers have often been neglected in discussions of marginal lands and bioenergy. There will not be any bioenergy production from marginal lands, or good agricultural lands, unless farmers benefit.

3. Redesign/repurpose existing agricultural systems

Worldwide, roughly 1500 MHa are under cultivation.[4] If these lands are to provide both food/feed and large-scale environmental services, then the larger systems in which land use are embedded must change. One such systemic change was described in a paper entitled 'Biofuels done right: land efficient animal feeds enable large

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environmental and energy benefits'.[5] The paper describes the use of double crops to increase the total amount of cellulosic biomass available for bioethanol production from currently farmed US croplands while maintaining food/feed production. Based on this system-level innovation, approximately 400 billion liters of bioethanol per year could be produced, the energy equivalent of about half of annual US gasoline consumption. On the environmental side, nitrate losses to groundwater and surface waters were decreased by 75% and total U S GHG production were reduced by 10%.

The basis of the double-cropping system is that row crops such as corn only occupy the land for a few months of the year, often less than half of the photosynthetically active period for plants. During the remainder of the year the land is essentially inactive. The sun is shining, but no photosynthesis is occurring because nothing is planted and growing. Double crops are often cool-season grasses whose most highly active photosynthetic periods are before or after the productive growth periods of food crops such as maize (corn). Typically the double crops are planted after corn or soybeans are harvested in the fall. They grow somewhat in the fall and over winter, grow rapidly in the spring, and then are harvested before the corn/soybean crop is planted in the early summer.[6]

The Biogasdoneright story

A national feed-in tariff was created in 2008 in Italy for renewable electricity. Inspired by the 'Biofuels done right'[5] paper, a group of farmers in northern Italy, in the Po River valley, decided to exploit farm-based anaerobic digestion (AD) units to produce biogas that would be burned on site to produce electricity for the national grid. Widespread double-cropping was adopted, whereas previously double-cropping was not widely practiced due to lack of markets for the double crop. The traditional crops were grown to supply the existing food/feed markets while the second or double-crop (primarily annual grasses such as winter rye, triticale, forage wheat, or corn silage after wheat grain, etc.) was grown, harvested, ensiled, and then fed to the digesters to enable year-round operation of the digesters. Digesters were also fed by animal manures and other wastes and residues.

AD is very flexible in the feedstocks it can process and is a relatively low capital cost technology without licensing requirements for processing technology or for commercial enzymes or bacteria with their associated costs. Net energy yields from AD are relatively high. The energy of the biogas represents approximately 24–65% of the heat of combustion of the inlet feedstocks supplied to the digester. Combustion of the biogas converts about 37–41% of the energy content of the biogas to electricity. Thus about 0.09–0.27 MJ of electricity is exported to the grid per MJ of feedstock energy.

Supply chains and biomass logistics are not an obstacle since these operations are confined to the farm. All the crop production and processing operations are conducted on the farm, and electricity is exported through the grid. Considering just the carbon, about 65–80% of the carbon fed to the digester is converted into biogas. The remaining carbon is incorporated into the soil.

Farms continue to produce food/feed from the first crop as they have always done; thus there is no impact on the food/feed markets and no market mechanism for indirect land-use change (iLUC) with its imputed GHG emissions. The double-crop produces additional carbon that is fed to the digester for bioenergy production. The liquid fraction from digestate is returned to the land by irrigation ('fertigation'), thereby recycling a large fraction of the mineral nutrients and providing irrigation water as needed.

The solids issuing from the AD unit are incorporated into the soil, increasing soil carbon levels and enhancing soil fertility. Soil carbon levels are further enhanced by the double-crop, primarily by decomposing roots from the double-crop. Thus the double-crop also increases soil organic matter and soil fertility.

Long-term digestate administration to the fields can lead to higher organic matter content of the soils. This practice enables long-term soil carbon sequestration. Thus the fertility of the farm increases over time by applying digester solid residues and the farm becomes more capable of food production, not less so. The double-crop reduces erosion, further protecting soils, and also captures mobile soil nutrients for recycling on the farm, thereby protecting water supplies. These positive effects of applying digestate can be further enhanced by practices derived from conservation agriculture such as minimum tillage, strip tillage and sod seeding, among others.[7] The overall system therefore functions as a biological carbon capture and sequestration (BECCS) process.

The approach is inherently flexible and scalable. Different crops appropriate for local soils and climates are grown in different areas. For example, farms in the temperate Po River valley, in the hot, arid regions of Sicily, and a number of farms in different regions between these extremes are participating in the *Biogasdoneright* movement.

In northern Italy, double-cropping often occurs as a mixture of winter cereals and nitrogen-fixing crops harvested in late spring for silage followed by corn harvested at grain maturity for the market or as triticale silage followed by soybean. Numerous combinations are possible. The key innovation is that one of the two harvests is ensiled and later fed to the digester.

In southern Italy, numerous double-cropping options are also possible. For example, durum wheat can be planted as the winter crop for the market followed by sorghum in the late spring or Italian sainfoin (a legume) for the winter followed the year after by durum wheat. This approach avoids mono-cropping with its attendant reduced grain protein content. Returning digestate liquid to the land also helps maintain protein content.

Since 2010, approximately 1200 AD units have been installed on Italian farms and have begun to produce renewable electricity. These units have a combined total electrical production capacity of about one gigawatt and feature an installed capital cost of about 3 million US$ per megawatt. About 12 000 new direct jobs have been created as a result of the growth in the AD industry in Italy.

Food production has not decreased on the farms that apply the guidelines. Participating Italian farmers are producing food and fuel. More ecologically intensive use of their land causes soil organic matter and soil fertility to increase. Recycling mineral nutrients reduces the cost of purchased fertilizers, and eliminates the GHG emissions associated with producing and using those inputs. Double-cropping and incorporating digestate solids significantly improve the GHG profile of these farms.

Income from food production remains the same, but input fertilizer costs are significantly reduced. Electricity produced is essentially another cash crop for the farmer. The presence of the digesters makes farm operations more resilient and robust. Even a failed food crop can be harvested and fed to the digester for energy production.

Critically, Italian farmers now have the ability to balance food and fuel production against each other. They can reduce the overall costs to society of both food and fuel while ensuring more stable and profitable operations for themselves. High food prices reduce energy costs at a given farm level profitability while high energy prices will enable lower food costs. Farms are thus less prone to boom and bust cycles of high crop commodity prices followed by long periods of depressed crop prices and the resulting bankrupt farms.

Different cropping systems can be used in different areas, but AD is the crucial technology that enables the success of this approach. Biological stabilization of manure and agro-wastes by AD clearly decreases related GHG emissions that would otherwise occur without AD. AD provides the biogas for electricity production or other uses and also the recycled nutrients and stabilized carbon for building soil organic matter. The digester creates the demand for the second harvest (the ensiled crop) that drives double-cropping and all of its attendant benefits. AD can be applied to arid regions not suitable for C3 and C4 crops. In such areas, the digester is fed with CAM plants, but without double-cropping. AD can also be applied to other erodible or degraded lands, for example, those planted with perennial grasses, again without double-cropping. In both cases, food (animal feed), energy, and large environmental services are generated, without requiring double-cropping.

These principles can be applied elsewhere in the world, adapting the principles to local circumstances and local needs. For example, a primary cause of illness and reduced life expectancy in sub-Saharan Africa is open-fire cooking and heating with wood. Applying *Biogasdoneright* principles at the African village level to process human and animal wastes, crop residues, and energy crops could improve soils while also providing some electricity and biogas for heating and cooking.

The foundation of bioenergy production is farms and commercial forests. Currently, many farms are going out of business due to low crop commodity prices. Low crop commodity prices are not good for farmers, nor are they good for a society that needs a stable, prosperous agricultural sector. We should promote policies and technologies that will lead to a sustainable, resilient agricultural sector that can help solve food, energy, and environmental problems.

If this is to be accomplished, we must redesign agricultural systems to produce food and bioenergy, while achieving large environmental benefits. The Italian *Biogasdoneright* movement provides an important, inspiring illustration of how both sustainable food and energy can be produced, while accompanied by large environmental services. It demonstrates how it is possible to simultaneously increase the economic viability and stability of agriculture by reducing farm input costs and enabling farmers to produce food and fuel more sustainably.

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