CLUB OF BOLOGNA

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"Energy use of biomass: a challenge for machinery manufacturers"

Conclusions and Recommendations

Session 1
Agriculture and energy

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CONCLUSIONS AND RECOMMENDATIONS

by *Luigi Bodria and Marco Fiala*

Luigi Bodria, President of the Club of Bologna, **49 experts** from **21 Countries and 1 representative of an International Organization** took part at the 22nd Meeting of the Club of Bologna, held on 13 and 14 November 2011 in Hannover (Germany), on occasion of Agritechnica 2011 and with the sponsorship of UNACOMA and DLG.

There was a general topic under discussion: "**Energy use of biomass: a challenge for machinery manufacturers**", which has been treated in **8 Key-Note Reports** subdivided into 3 Sessions.

The Session 1 - **Agriculture and energy** concerns a general overview on a large-scale system for bioethanol production, as well as, on the present situation concerning agro-energy application in Europe. Two reports have been presented:

- **Developing an integrated agro-industrial model for the sustainable production and conversion of biomass into biofuels and added value products**, by Prof. Paulo Seleghim (University of São Paulo, Brazil);
- **Technologies for biomass conversion: an overview and aspects to be developed**, by Prof. Giovanni Riva (Politechnic University of Marche, Italy).

The Session 2 - **Energy production from biomass** considers the the most relevant technical innovations and the near future prospects for the agro-energy systems. Four reports have been presented:

- **Biogas – energy from anaerobic digestion**, by Detlef Riesel (Agency for Renewable Resources, Germany);
- Improvement **of the technical, economical and ecological efficiency of biogas production. Future challenges for the agricultural engineering sector**, by Dr. Helmut Döhler (Ass. Technology and Structures in Agriculture, Germany);
- **Overview on biofuel technologies: feed-stocks and processes development**, by Dr. David Chiaramonti (University of Florence-CRAER, Italy);
- **Supply of wood biomass for energy purpose: global trends and perspectives**, by Dr. Raffaele Spinelli (CNR-IVALSA, Italy).

The Session 3 - **Energy from biomass: final use**: concerns the state of the art in using biofuels to run tractors engines. Two reports from tractor's manufacturers have been presented:

- **Same Deutz-Fahr vision and experience with pure - esterified (RME/FAME) and non-esterified (RSO), vegetable diesel fuels for agricultural tractors**, by Dr. Massimo Ribaldone (SDF Group, Italy);
- **Biofuel use on tractors**, by Dr. Giuseppe Gavioli (CNH).

CONCLUSIONS

Session 1 - Agriculture and energy

The first Keynote Report "**Developing an integrated agro-industrial model for the sustainable production and conversion of biomass into biofuels and added value products**", presented by Prof. Paulo Seleghim from University of São Paulo (Brazil), is focused on the present system of bioethanol production in Brazil analyzing also the possibility to produce this biofuel using lingo-cellulosic biomass.

Using sugar cane bagasse to obtain second generation cellulosic ethanol is a very efficient use of this resource. This is evident since a typical Brazilian sugar cane processing industry utilizes 500 t/h of sugar cane to produce about 45 m^3/h of the first generation ethanol. Conversion of 150 t/h of bagasse can yield electricity at a rate of 50 MW. Alternatively, this bagasse could be turned into mulch from which it is possible to extract 42 m^3/h of second-generation ethanol obtaining approximately a doubled ethanol production without the increasing of sugar plantation area. Such conversion way is – at the moment - restricted to research laboratories and small scale demonstration plants; the main reason for this problem is the lack of industrial large scale processing technologies that are efficient and environmentally safe. Moreover, there are no comprehensive studies in which all stages of production of cellulosic ethanol have been optimized, both in terms of productivity and in terms of generation of pollutants. Current research and development projects in Brazil are focusing on these technological bottlenecks and hurdles associated with each of the stages of the conversion process: 1) pre-treatment for the destruction of the macroscopic structures of biomass, 2) enzymatic hydrolysis to saccharify the ligno-cellulosic material, 3) production of enzyme cocktails, 4) obtainment of yeast for industrial fermentation of sub products resulting from pre-treatment and from enzymatic hydrolysis, 5) fermentative processing for cellulosic ethanol production, 6) recovery of waste for energy production and chemical inputs.

The second Keynote Report " **Technologies for biomass conversion: an overview and aspects to be developed**", presented by Prof. Giovanni Riva from Polytechnic University of Marche (Italy), highlights some aspects related to the energy use of biomass that may interest the industry of agricultural equipment in the current European context.

The issue of the biomass for energy uses is an important element of the EU policy, despite the current not positive economic situation. However, the development of biomasses for energy uses, supported by a long-term political strategy has several positive aspects for both the agricultural sector and all the connected industries.

Biomass is usually widespread at regional level or concentrated in large quantities at processing centres as process by-products or waste materials collected for disposal. Taking into account some important issues, like environmental and socio-economic aspects, the residual biomass and a selected number of energy crops represent a potential interest for European operators. Among the conversion technologies, the most interesting solutions for the market seem to be the following:

- complex systems for the production of raw materials (bio-refineries), biofuel and/or energy to be distributed by networks. Currently, these systems are almost specialized in the production of a single biofuel;
- small/medium energy conversion systems based on biochemical or thermochemical processes (district heating plants with or without cogeneration; power plants and biogas plants connected to the grid);
- small-scale production of thermal energy for industrial or residential sectors (stoves and small size boilers).

Real bio-refineries are not yet operational, while other examples are of real interest for the market and well developed. With respect to the mechanical operations that take place before the energy conversion of residual biomass (e.g.: cereal straw, maize stalks, forest residues, etc.) and energy crops (e.g.: herbaceous crops, short rotation forestry, etc.) the following steps must be highlighted: biomass harvest and collection, storage, handling, pre-treatment and transportation. All these activities require a lot of work for their development especially in terms of reduction of the relevant costs.

Session 2 - Energy production from biomass

The first Keynote Report "**Biogas – energy from anaerobic digestion**" presented by Detlef Riesel from Agency for Renewable Resources (Germany), considers the main aspect concerning the biogas plants operating in farm conditions.

Within the supporting regulatory framework biogas plays an important role in Germany. Since the Renewable Energy Sources Act (EEG) is in force the number of plants has grown by five times and the installed electrical capacity has risen by 24 times. At the end of this year there are 7000 plants expected in Germany with an electrical capacity of more than 2,700 MW. With this performance 3.7 million households could be supplied with electricity.

After a wide overview on the technical solutions commonly adopted in a biogas plant, with a particular attention to the German farming conditions, the different possibilities of biogas use are discussed. The most common utilization is to produce electricity in a combined heat and power plant (CHP). Economically valuable and environmentally

beneficiary is this process only if the produced heat can be used also. Other utilizations are power production with micro-turbines, Stirling engines and fuel cells or heat production by burning the gas in boilers or burners. With different technologies biogas can be upgraded to natural gas quality (methane content >80%). By this biomethane is feed into the natural gas grid and can be transported at any distance. This solution represents a good alternative to the decentralized CHP utilization; another possible utilization is given in the transport sector: biomethane can be used as fuel in every natural gas vehicle. This is already very popular in Sweden and Switzerland. Besides the produced gas also the digested substrate (digestate) is a valuable soil fertilizer, which can be applied on soils with the usual equipment for application of liquid manure.

Construction and operation of a biogas plant and spreading of the digestate have to follow a number of laws and regulation; these requirements include planning, construction, water, nature protection, waste, pollution control, fertilizer and food hygiene legislation.

The second Keynote Report "**Improvement of the technical, economical and ecological efficiency of biogas production. Future challenges for the agricultural engineering sector**", presented by Dr. Helmut Döhler from Association of Technology and Structures in Agriculture (Germany), relates on biogas plant's German situation considering also the several possibilities to increase the competitiveness of the biogas energy production in the near future.

Biogas as compared with other bioenergy sources shows several advantages: It can be produced sustainably from various biomass and its energy may be used in many ways and needs. The success of the biogas technology is measured not only in the continuous growth of plant numbers, but also to the efficient and sustainable production of electricity, heat and fuel. Biogas plants are then economically and ecologically meaningful, if they are process-optimized operated and if resources are used effectively.

The cost of producing biogas and photovoltaic electricity in Germany today are at similar levels. Despite the increase in the efficiency of biogas production, rising costs of the manufacturing of plant components and the substrates (biomass) further cost reductions are not expected any more. By technological advances in the semiconductor industry and mass production, however, the costs of photovoltaic power from 90 to 15 c€/kWh were reduced drastically. Thus increasing their competitiveness, unlike other renewable energy sources from biomass. Electricity generation in biogas plants will compete with other options for generating renewable energy when tending the net emissions of greenhouse gases to zero. This then results in economically acceptable mitigation costs of less than 100 €/t CO_2.

Highest priority for research and development for the agricultural engineering sector is on those process steps of the generation of biogas that can help to reduce greenhouse gas emissions at low or neutral net costs. These are mainly the technical developments for the use of non land consuming substrates, techniques for the disintegration of lingo-cellulose, the avoidance of methane leakages, the further increase of the CHP efficiency and techniques for the efficient use of surplus heat.

The third Keynote Report "**Overview on biofuel technologies: feed-stocks and processes development**", presented by Dr. David Chiaramonti from University of Florence-CRAER (Italy), gives an overview of the current status in the field of biofuel technologies.

The ongoing technological development in the field of bioenergy and biofuels represents a breakthrough for the sector. After the Renewable Energy Directive EC/28/2009 and the Fuel Quality Directive EC/30/2009, Member States have developed National Action Plans to implement strategies to achieve the targets set by the Directive. The role of bioenergy is relevant and constitutes a cornerstone towards the goals. This legislative effort has created the conditions for the development of new processes and technologies, with particular respect to 2nd generation biofuel. This term is used to indicate the liquid fuels derived from ligno-cellulosic biomass through thermochemical, biochemical or combination of these two processes. The lingo-cellulosic biomass can be grown in marginal or low productive lands, thus reducing the conflict with food production. This is a remarkable difference compared to traditional oil or sugar crops. In addition, the land needed per unit of products is extremely lower than the 1st generation crops and specific costs (€/dry ton) are lower as well.

The lingo-cellulosic biomass can then be either fractionated through specific pre-treatment processes in the basic components hemicellulose-cellulose-lignin (for instance, steam explosion followed by enzymatic hydrolysis) or transformed in a gas mainly constituted by H_2 and CO (and different amounts of contaminants for the downstream

processes). Then, either biological steps based on microorganisms transforming sugars in ethanol and other products or cleaning, reforming and synthesis is applied to the gas produced from biomass. This second process is called BTL (Biomass-To-Liquid, analogously to CTL - Coal To Liquid or GTL - Gas To Liquid, both already existing processes).

The technological requirements for the feedstock can be significantly different for thermochemical or biochemical process both in terms of physical conditions (drying and comminution) and chemical aspects (content and composition). As regards the industrial status of these biofuel production paths, the lingo-cellulosic ethanol has today achieved a full demonstration scale (order of tens of thousands of tons of ethanol produced per year), while the few demonstration initiatives in EU to develop thermochemical demo plants are currently moving forward slower than expected. This will most likely have an impact on the commercialisation of second generation biofuel in the coming years.

The fourth Keynote Report "**Supply of wood biomass for energy purpose: global trends and perspectives**" presented by Dr. Raffaele Spinelli from CNR-IVALSA (Italy), presents a deep analysis on the mechanization requirements in production of woody (from forests and/or from fields) biomass for energy conversions.

Energy biomass presents a large potential for expansion and may grow faster and further than any other related sector. What's more, biomass is produced in forests and fields, and appeals to a rural world that has few other opportunities. In many European countries, forestry and agriculture are no longer competitive on the world market, and they have not been for many years.

They have survived on subsidies, whose availability has kept shrinking over time. There is a will to make European forestry and agriculture more competitive on the global market, but that is made difficult by the falling production prices of most agricultural stocks. Biomass will never entirely replace oil, but it may play an important role in a concerted strategy aiming at its substitution. That depends on the capacity of mobilizing very large amounts of raw material, exploiting a significant proportion of the quantities potentially available. The rural world is in the front line, because it controls the land, which is the ultimate source of biomass. Foresters and farmers need to become aware of this opportunity and to learn how to exploit it correctly. In turn, this will generate great opportunities for agriculture and forestry mechanization, which machine manufacturers must be ready to seize.

Session 3 - Energy from biomass: final use

The first Keynote Report of this last session "**Same Deutz-Fahr vision and experience with pure - esterified (RME/FAME) and non-esterified (RSO), vegetable diesel fuels for agricultural tractors**" presented by Dr. Massimo Ribaldone from SDF Group, relates on the experience of this important manufacturer about the use of vegetable biofuels for fuelling agricultural machines and, in particular, tractors.

Since the 80's Same Deutz-Fahr has tested tractors suitable to use biodiesel and nowadays is one of the most important tractor maker with mid power ranges suitable to be fuel both rape seed oil methyl ester and pure vegetable oil. The most common vegetable oil methyl ester in Europe is rape seed oil methyl ester named RME or biodiesel. A tractor fleet has been tested with successful and today the Same Deutz-Fahr tractors can be filled fully with RME (B100). Comparative tests with standard diesel fuel have shown loss of output power of 5-7%, oil change interval reduction. Moreover long downtimes must be avoided with biodiesel. Instead, the engine must be operated and shut down with diesel fuel before laying up. Many engine and fuel hydraulic circuit have to be replaced with bio-diesel-resistant materials. The advantages of bio diesel versus diesel fuel are: (i) lower soot emission (- 50%), (ii) lower PM emission (-30%), (iii) CO_2 global reduction and lower sulphide content. More (+15%) NO_x pollution is expected like increased fuel consumption (+5%).The engine performances in terms of dynamic behavior are in line with the standard version. No major reliability complaints came up from the tests.

In 2008 Same Deutz-Fahr introduced in the market the first tractor range above 90 kW suitable to be fueled by pure vegetable oil (rape seed oil) .The 4 valve common rail engine complies with Stage 3A emission. A special fuel hydraulic circuit has been implemented for managing the warm up and switch off engine phases. The pure vegetable fuel due to high viscosity, low cetane number (40-42), high carbon residue and unfavorable low temperature characteristic is much more difficult to manage respect to RME and standard diesel fuel. The successful tests have been done in Germany where a specific engine electronic control has been developed for taking into account the pure fuel features. Tractors tested ran with only minor disturbances. All of the others suffered damage ,up to and including total failure , primarily due to: defective fuel injection pumps and nozzles, seizing exhaust valves and individual cases of piston

seizure. The pure vegetable oil is the most convenient fuel compare with RME and standard fuel due to the low industrial cost and , for the time being ,absence of taxes.

The second Keynote Report "**Biofuel use on tractors**" presented by Dr. Giuseppe Gavioli from CNH, considers the different possibilities in biofuel use recently exploited by the CNH group on some tractors.

Traditional agricultural tractors have internal combustion engines propelled by diesel fuel that is derived from crude oil. Several drivers exist to decrease dependence from crude oil: environmental benefits, energy security, economics: the adoption of bio fuels is one of the more effective answers to the problem.

There are several kinds of bio-fuels, liquid (e.g. biodiesel, BtL, bioethanol -1st and 2nd generation) and gaseous (e.g. biomethane, hydrogen). The key thing is that all of them can be derived from agricultural and forestry products and animal waste: so they are a renewable source of energy. The bio fuels have also good environmental properties, like lower gaseous emissions than conventional fuels and a more sustainable carbon footprint.

With the production of bio fuels the key assets become land and agricultural mechanization. And one of the key challenges becomes logistics. So a virtuous circle is built, with bio fuels that propel tractors and tractors that "produce" bio fuels by working the land and harvesting energy crops.

RECOMMENDATIONS

Session 1 - Agriculture and energy

- ✓ **noticing** that development of biomasses for energy uses must be supported by a long-term political strategy and it has several positive aspects for all the agricultural sectors;
- ✓ **underlining** that the production of biomass for energy conversions must find a shareable balance with food producing biomasses without introduce any competitiveness in soil use;
- ✓ **considering** that biomass constitutes a very promising source of energy and, particularly, first and second generation ethanol can play a significant role in displacing fossil automotive fuels in a global scale;
- ✓ **recalling** that techniques for energy generation from biomass must be deeply analyzed to determine the cost and benefits from economic, energy and environmental perspectives;

the Participants unanimously:

- ✓ **encourage** the Club of Bologna to emphasize the central role of agriculture in energy generation both in large-scale plants for biofuel production as well as in small-medium size plants for a direct use of energy locally generated (thermal and electricity);
- ✓ **confirm** the need to develop the appropriate mechanization technologies for energy crops production;
- ✓ **acknowledge** that the conversion of agricultural products and/or byproduct into energy needs to take into consideration several aspects concerning the respect of environmental balance and, in particular, the preservation of soil fertility, water supply, reduction of erosion;
- ✓ **invite** to undertake any possible effort for the development of an energy policy devoted to face the environmental issue end to reduce the climate change.

Session 2 - Energy production from biomass

- ✓ **considering** that biomass use for energy is a real world-wide trend; even though a lot of technical and ethical questions are still on the table, the change from a fossil fuel to a renewable energy economy is started;
- ✓ **underlining** that some biomass-to-energy process already present interesting energy I/O balance; it is the case of the large scale ethanol production from sugar cane under Brazilian conditions as well as the local biogas production in anaerobic digestion plants fed by animal manure and/or agro-industrial residues under EU farming conditions;

- ✓ **noticing** that biomass harvesting, transport and logistics are crucial aspects of the whole conversion system in order to achieve a full sustainability; in particular: the densification of row materials for biofuel production and wood biomass and the use of cellulosic raw biomass treated by extrusion for biogas system;
- ✓ **recalling** that it will be very important to move from 1st to 2nd generation technologies for biofuels production in order to assure a complete sustainability of the processes;

the Participants unanimously:

- ✓ **encourage** the Club of Bologna to reinforce studies on the most appropriate balance between food and energy crops with the aim to evaluate the possible contribution of energy from biomass in the industrialized countries;
- ✓ **confirm** the need to promote researches on second generation biofuel from lingo-cellulosic material in order to overcame the competitiveness between food and energy as well as on a network of biogas farm plants mainly fed by a livestock slurry for biomethane production to be integrated in national gas network;
- ✓ **acknowledge** that cultivation and transformation of biomass represent a new and important valuable product in order to increase the farmers income;
- ✓ **invite** to study in deep process and machines to produce high energy density materials in agricultural field.

Session 3 - Energy from biomass: final use

- ✓ **considering** that the increasing energy consumption coming from growing countries and the environmental requirements have brought the world to look for alternative petroleum energy sources for fueling the on road and off road machines;
- ✓ **underlining** that electrification and new vegetable fuels are more and more under investigation for seeing their potential suitability in terms of costs, environment, social effects, performances for replacing without any relevant weakness points fuels coming from petroleum;
- ✓ **recalling** that the adoption of bio fuels for fuelling tractor's engines is one of the more effective answers to the problem to decrease dependence from oil and greenhouse gas emission;
- ✓ **acknowledge** that the utilization of biofuel on tractors and self-propelled machines is base on existing or quickly developing technologies so technical problem will find smart solutions;

the Participants unanimously:

- ✓ **encourage** the Club of Bologna to emphasize the need for a system approach for biofuel utilization including appropriate mechanization chain for efficient biomass production;
- ✓ **acknowledge** that quality and standardization of biofuel is a key issue in order to set up a flexible power system with new fuel alternatives for the farmers/producers;
- ✓ **underline** that diffusion of biofuel needs not only technical improvement but also public agreement on higher sale prices compared to environmental benefits;
- ✓ **confirm** that the issue of energy-independent farm is very appealing but evaluation of farm-produced fuel should account for efficiency, sustainability, environment effects, as well as land and other resources required.