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NEXT GENERATION BIOFUELS: WHY, WHAT, HOW, WHEN? ICS-UNIDO PROGRAMME AND ACTIVITIES IN THE FIELD

Abstract: The paper presents a brief introduction to the basic aspects of next generation biofuels, briefly detailing on the technology options, environmental and costs aspects. Emphasis is placed on the need to promote the development of next generation biofuels in developing countries and countries with economies in transition as of a promising opportunity to improve social economic conditions and to move towards a new more sustainable outlined.

Key words: *next generation biofuels, production technology, economic and environmental assessment, UNIDO, developing countries*

INTRODUCTION

The decrease of fossil reserves together with their impact on the environment in terms of greenhouse gas emissions have stimulated exploration of renewable sources of energy. Most modern renewable energy source options (wind, solar, tides, hydro, geo, etc.) are suitable for electricity production and their development nowadays shows very favourable tendencies. The ancient renewable source of energy is the biomass which has been widely used for energy generation (mainly heating and cooking applications) for centuries. However, most these applications are have little efficiency. Even though the recent concept of biomass use for heat and power generation brings improved technologies for better efficiency and allows on-site electricity production, which is a valuable benefit to distant habitations, the most promising long term strategy of biomass use appears to be the exploitation of the value of its matter: either for energy or material applications. That is we are talking about

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biofuels and chemicals from biomass. Currently, only 2% of biomass is used in the transportation sector [1].

There are several other drivers of the biofuels development, such as: 1) diversification of feedstocks for fuel production (energy security to regions poor of fossil resources), 2) valorisation of waste biomass (solution for waste management issues), 3) stimulation of green chemical industry (more environmentally sustainable chemical processes to be adopted in the production of biofuel and chemicals from biomass with respect to the traditional oil refineries), 4) integration of industry and agriculture (stimulation of feedstock production), 5) social benefits to developing countries (improvement of countries economic conditions through industrialization and rural development) most of which are rich of bioresources.

NEXT GENERATION BIOFUELS AND BIOREFINERIES

The chaotic development of biofuels in the recent years has shown how unsustainable practices can be detrimental for the society and the environment [2–5]. The competition with food and the generally low eco-compatibility of the technologies for producing "first generation" biofuels (from crops or vegetable oils) has fostered the need of new generation biofuels produced from other types of biomass, as well as using more sustainable technologies. These feed resources will not compete with food production, but instead will foster the food production allowing developing integrated agro-energy districts for a better rural economy. These "next generation" biofuels will be based on agricultural and other lignocellulosic waste (e. g. forestry), waste oils, algae biomass, by-products of some bio-based industries (e. g. glycerol from biodiesel production by transesterification), etc. [6]

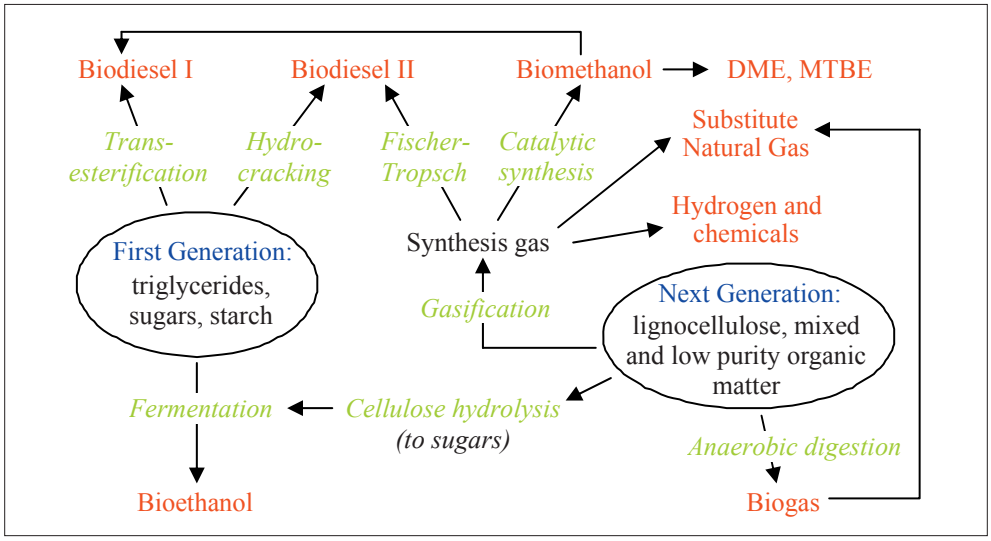

Figure 1. Schematic of the production pathways of various biofuels of first and next generations [8].

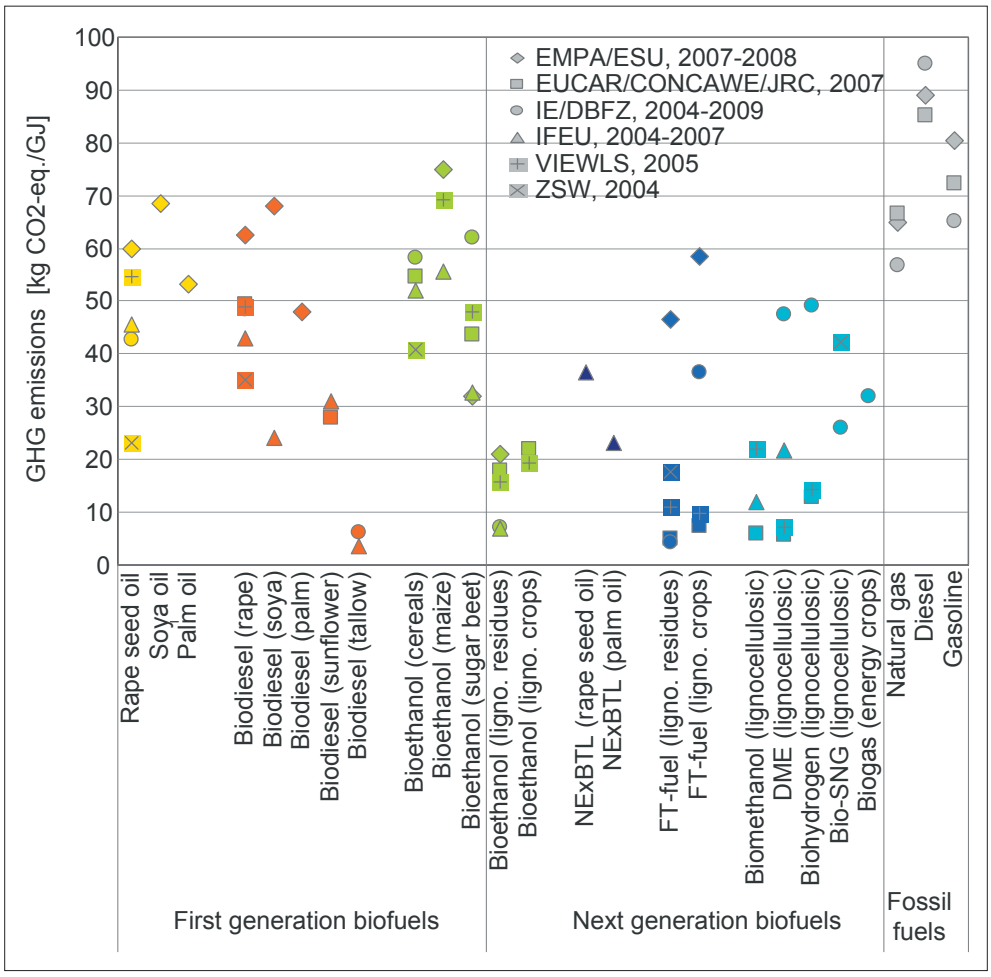

Figure 2. International results on global warming potentials (average values) [9–14].

The next-generation biofuels under attention of chemists and technologists currently include: advanced biodiesel or hydrogenated vegetable oils (HVO), synthetic biofuels (e. g. FT-diesel, bio-MeOH, bio-DME, bio-SNG, and bio-MTBE), biomethane (via biogas), lignocellulosic bioethanol, and bio-hydrogen. The scheme in Figure 1 generally illustrates a variety of technology pathways to produce biofuels of first and next generations, i. e. those obtained from energy crops (sugar, triglycerides, starch) and from waste biomass (lignocellulose, mixed organic matter, low quality oils, etc.). More detailed info on specific production technologies and related aspects of chemistry and catalysis can be found elsewhere [7].

An expanding biomass usage should also follow environmental criteria. Results of a several LCA (Life Cycle Analysis) studies on a number of biofuels are combined in Figure 2. One can easily note that according to most sources the next

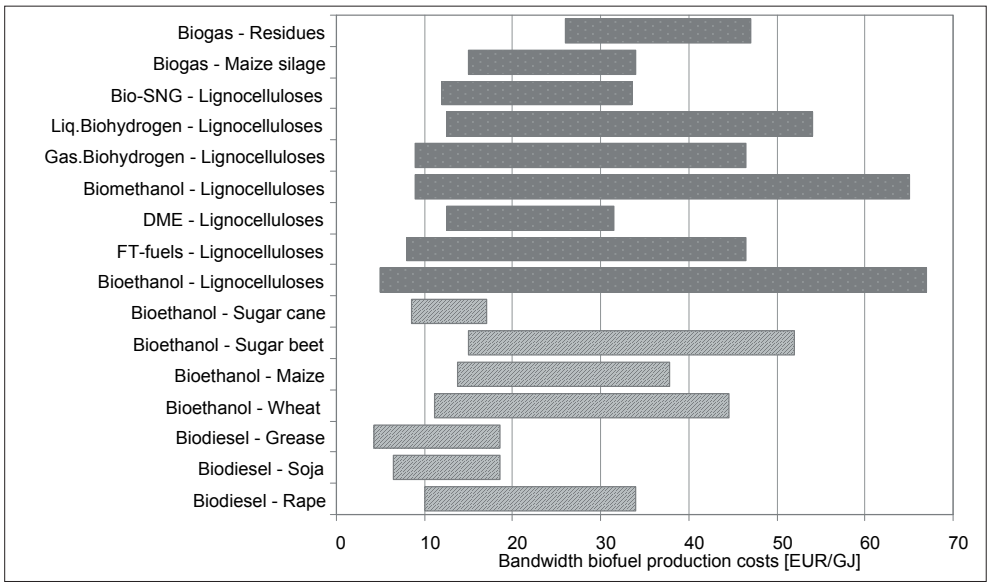

Figure 3. Biofuel production costs [15–23].

generation biofuels show reduced emissions with respect to traditional biofuels and fossil fuels. Even for the same product, the environmental impact in terms of GHG emissions related to biofuels production stems from conjunction of many factors, which include feedstock type and conditions of its cultivation and harvesting, transportation and specifics of conversion technology, etc. Hence, results of different LCA studies can vary in a wide range.

Coming to the production costs of biofuels (see Figure 3), next generation biofuels still appear quite cost intensive due to a number of factors, such as technology complexity and availability, feedstock transportation & storage due to large scale requirements, infrastructure, etc.

An appropriate way to improve the economy of next generation biofuels, as well as of traditional biofuels and of other bio-based production processes is the integrated approach of production of high added value chemicals together with target products (biorefinery concept). Biorefineries are seen as the future facilities of the bio-based industry as they present the most sustainable solution of bio-resource management in terms of technical economic and environmental benefits.

ICS UNIDO PROGRAMME IN THE FIELD OF BIOFUELS AND BIO-BASED CHEMICALS

United Nations Industrial Development Organization (UNIDO) was instrumental in promotion of the industrial development through the transfer of technologies in the energy sector in developing countries and countries with economies in transition. The UNIDO Biofuels Strategy was developed in 2007 in order

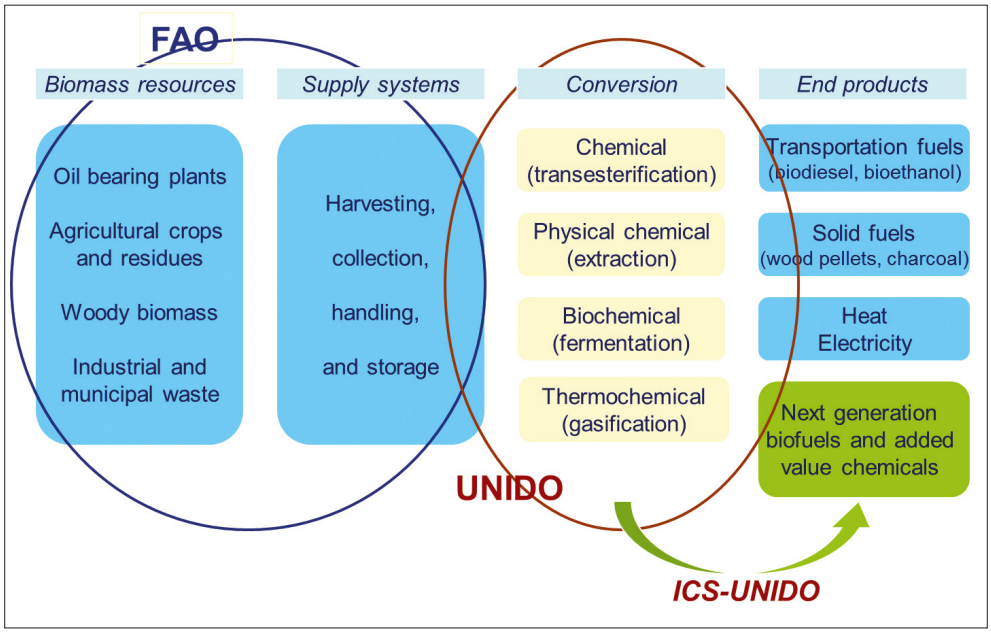

Figure 4. Radius of attention of UNIDO and of ICS in the biofuel production chain [25]

to identify the potential areas of UNIDO intervention and its role in promotion of the national and international programmes related to biofuels. The radius of attention is placed primarily on the conversion technologies (see Figure 4).

The International Center for Science and High Technologies (ICS) operating in the framework of UNIDO is committed to the provision of technical and scientific assistance to the UNIDO projects in developing countries in selected priority fields one of which is the biofuel production processes. ICS' main activities include capacity building, training, and research. Since 2007, in the framework of its biofuels programme ICS has organized 10 workshops, expert group meetings, and training courses which were aimed at capacity building and spreading awareness, as well as at strengthening cooperation with institutions from developing countries and countries with economies in transition. Training of young scientists and technologists from these beneficiary countries has being performed in the framework of the ICS fellowship programme which foresees participation of fellows in research activities and in development of ICS products and tools (on-job training). Each year, approximately 7 fellows come to ICS and to the laboratories of its cooperating centers to participate in the ICS research projects which focus on chemical studies of conversion technologies for exploitation of waste and low grade bio-feedstock, such as glycerol from biodiesel production, lignocellulosic waste, and waste vegetable oils for production of biofuels and added value chemicals in the context of biorefinery. Some specific research projects include: 1) biohydrogen production via catalytic aqueous phase and photo-catalytic reforming of glycerol, 2) enzymatic

degradation of lignin using laccases, 3) lipase catalyzed transesterification of waste oils, 4) valorization of dehydro-sugars from cellulose hydrolysis via heterogeneous catalysis, 5) modeling study of the enzymatic cellulose hydrolysis by cellulases, 6) development of decision support tools for assessment of sustainability of biofuels. For more information on ICS activities and its biofuels programme please see elsewhere [24].

CONCLUSION

Development, even in the embryonic phase, of biofuels and of bio-based chemicals under the biorefinery concept in developing countries and countries with economies in transition has to be supported. Whereas strategic scenarios can be different for different countries, depending on resource availability and other factors, preliminary steps can be taken for the purpose of demonstration and spreading awareness among decision makers, general public and specialists. Thus, small scale biorefineries based on the existing agricultural production can be already now short term priority goals for many developing countries. Introduction of next generation biofuels on pilot scale (nonfood feedstock based) also has to be promoted in selected countries. Last but not the least, specialized human and institutional capacity in R&D, in basic research, and in dedicated education programmes in the field needs support widely on the local level. ICS and UNIDO are actively working in these directions. Their programmes are aimed at stimulation of cooperation with local scientific community, SME and industry as well as with local public entities. In this regard, both cooperation with industrialized countries (South-North cooperation) and among developing countries and countries with economies in transition (South-South cooperation) are addressed.

To adopt the most appropriate strategies of production of biofuels and bio-based chemicals countries have to assess sustainability of different production processes, taking into account a together of related technical, social economic and environmental indicators. Sustainability of production processes has to be the key element in the development of related policies.

LITERATURE

[1] Data from International Energy Agency, 2007.
[2] A. E. Farrell, R. J. Plevin, B. T. Turner, A. D. Jones, M. O'Hare, D. M. Kammen, *Science*, 2006, *311*, 506.
[3] D. Rokityanskiy, P. C. Beniez, F. Kraxner, I. McCallum, M. Obersteiner, E. Rametsteiner, Y. Yamagata, *Technol. Forecast. Soc. Change*, 2007, *74*, 1057.
[4] J. Fargione, J. Hill, D. Tilman, S. Polasky, P. Hawthorne, *Science*, 2008, *319*, 1235.
[5] T. Searchinger, R. Heimlich, R. A. Houghton, F. X. Dong, A. Elobeid, J. Fabiosa, S. Tokgoz, D. Hayes, T. H. Yu, *Science*, 2008, *319*, 1238.
[6] C. N. Hamelinck, A. P. C. Faaij, *Energy Pol*., 2006, *34*, 3268.
[7] S. Zinoviev, F. Mueller-Langer, P. Das, N. Bertero, P. Fornasiero, M. Kaltschmitt, G. Centi, S. Miertus *ChemSusChem*2010, no. 3, 1106–1133.

[8] S. Zinoviev, S. Miertus *Chimica & Industria* 2008, no. 5, 106–112.
[9] M. Kaltschmitt, H. Hartmann, *Energie aus Biomasse – Grundlagen*, Techniken und Verfahren (Springer-Verlag, Berlin, Heidelberg) 2001.
[10] T. Ekbom, N. Berglin, S. Lögdberg, *Black liquor gasification with motor fuel production – BLGMF II, A technoeconomic feasibility study on catalytic Fischer-Tropsch synthesis for synthetic diesel production in comparison with methanol and DME as transport fuels*, Final report P 21384–1 for Swedisch Energy Academy Dec. 2005. http://www.nykomb-consulting.se/pdf/BLGMF_II.pdf (Retrieved on Jan. 2010).
[11] G. Reinhardt, *An Assessment of Energy and Greenhouse Gases of NExBTL*. Institute for Energy and Environmental Research GmbH by order of the Neste Oil Corporation, Porvoo, Finland, Heidelberg, June 2006.
[12] M. Quirin, S. O. Gärtner, M. Pehnt, G. A. Reinhardt, CO 2-Studie – CO 2-neutrale Wege zukünftiger Mobilität durch Biokraftstoffe: Eine Bestandsaufnahme. Institut für Energie- und Umweltforschung Heidelberg GmbH (IFEU), Studie im Auftrag der Forschungsvereinigung Verbrennungskraftmaschinen (FVV), Heft 789, Frankfurt am Main, 2004.
[13] R. Zah, H. Böni, M. Gauch, R. Hischier, M. Lehmann And P. Wäger, (EMPA): Ökobilanz von Energieprodukten: Ökologische Bewertung von Biotreibstoffen. Empa – Abteilung Technologie und Gesellschaft, Bern, Mai 2007.
[14] A. Wakker, R. Egging, E. Van Thuijl, X. Van Tilburg, E. Deurwaarder, T. De Lange, G. Berndes, and J. Hansson, *Biofuel and Bioenergy Implementation Scenarios*. Final report of VIEWLS WP 5, modelling studies. Senter Novem et al., Petten, 2006.
[15] B. Kavalov, S. D. Peteves, *Status and perspectives of biomass-to-liquid fuels in the European Union*, Report EUR 21745 EN, European Union (Brussels, Belgium), 2005. http://www. mangus.ro/pdf/Stadiul%20actual%20si%20perspectivele%20 bio-combustibililor%20in%20Europa.pdf (Retrieved on Jan. 2010).
[16] C. Gangl, *Ethanolerzeugung aus stärkehaltigen Rohstoffen zur Treibstoffzwecke*, Thesis (Univ. für Bodenkultur Wien, Austria) Sept. 2004. http://www.wiso.boku.ac.at/fileadmin/_/H73/H733/pub/Biogas/2004_DA_Gangl.pdf (Retrieved on Jan. 2010).
[17] R. Doornbosch, R. Steenblik, *Biofuels: Is the cure worse than the disease?, Round table on sustainable development, Organisation for Economic Co-operation and Development*, OECD, SG/SD/RT (2007)3, Paris, Sept. 2007. http://www.oecd.org/dataoecd/15/46/39348696.pdf (Retrieved on Jan. 2010).
[18] C. H. Hamelinck, G. V. Hooijdonk, A. P. C. Faaij, *Prospects for Ethanol from lignocellulosic Biomass: technoeconomic performance as development progresses*, Report NWS-E–2003–55, University Utrecht Nov. 2003. https://www.senternovem.nl/mmfiles/149043_tcm24–280055.pdf (Retrieved on Jan. 2010).
[19] M. Quirin, S. O. Gärtner, M. Pehnt, G. A. Reinhardt, CO 2-neutrale Wege zukünftiger Mobilität durch Biokraftstoffe: Eine Bestandsaufnahme. Institut für Energie- und Umweltforschung Heidelberg GmbH (IFEU), Studie im Auftrag der Forschungsvereinigung Verbrennungskraftmaschinen (FVV), Heft 789, Frankfurt am Main (Germany), 2004. http://www.ufop.de/downloads/Co2_neutrale_Wege.pdf (Retrieved on Jan. 2010).
[20] N. Schmitz, J. Henke, G. Keppler, Biokraftstoffe eine vergleichende Analyse. Fachagentur Nachwachsende Rohstoffe e. V. mit finanzieller Förderung des Bundesministeriums für Ernährung, Landwirtschaft und Verbraucherschutz, Gülzow (Germany) 2006.
[21] E. V. Thuijl, C. J. Roos, L. W. M. Beurskens, *An overview of biofuel technologies, markets and policies in Europe*. Energy research Centre of the Netherlands, Report

ECN-C--03–008 Jan. 2003. http://www.ssc.it/pdf/2005/biofuel_UE2005.pdf (Retrieved on Jan. 2010).
[22] A. Wakker, R. Egging, E. van Thuijl, X. van Tilburg, E. Deurwaarder, T. de Lange, G. Berndes, J. Hansson, *Biofuel and bioenergy implementation scenarios, Final report of VIEWLS WP 5, modelling studies.* Senter Novem et al., Petten (Netherlands) 2006. http://www.risoe.dk/rispubl/NEI/nei-dk-4610.pdf (Retrieved on Jan. 2010).
[23] Vogel, A.; Müller-Langer, F.; Kaltschmitt, M. *Chem. Eng. Technol.* 2008, 31, no. 5, 755–764.
[24] Adapted from *UNIDO Biofuels Strategy* (2007).
[25] For more info see www.ics.trieste.it.