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A CHANCE TO BIOFUELS FOR A CHANCE TO AFRICA

WILL THE TECHNOLOGY MAKE CHANGE?

New technologies for production of biofuels and for energy generation from waste biomass open up promising opportunities for human and industrial development in Africa, a continent rich of bioresources and unexplored potentials The solutions are reachable but need sustainable implementation to secure food and the environment.

Strong criticism has been drawn recently against the rapidly growing field of biofuels. While advocated by ones because being justified by the issues of climate change and growing oil prices, biofuels are blamed by others for being responsible for high food prices and even food crisis in some countries. The strong campaign by mass media and some public organizations against biofuels resulted in stopping the bio-ethanol investments in the US, temporary closure of some bio-diesel plants in Europe, and limitations of biodiesel production rates in the leading biofuel producers Brazil and Malaysia.

Are the biofuels just a false remedy from the environmental crisis that bring about another malady or we are dealing with the inflated problem due to the speculations on the unsustainable planning and lack of policy in biofuels? And if the global development of this emerging sector is questionable even in the more developed countries, is there any sense for the Third World to get involved now? Maybe we need to look into this problem more locally. The answer of the experts representing various African countries at the International Conference on Renewable Energies in Africa held in Senegal was "yes", Africa needs biofuels as it needs to explore new and sustainable forms of energy: "*It is common knowledge that Africa is blessed with a vast resource endowment; with resources and could and should be used to promote the industrial growth of African countries and their subsequent integration into the world economy, and thereby the broader economic development of these countries. [...] One missing link so far has been industrial applications of renewable energy technologies. Using raw materials such as agricultural wastes to generate energy can add value to these products and can help to offset unreliable energy supplies from national grids*" (Kandeh Yumkella, Director-General of UNIDO, International Conference on Renewable Energies in Africa, Dakar (Senegal) 16-19 April 2008).

Biofuels and bio-energy, as well as the various other types of renewable energy like solar, wind, geothermal, etc. can be an opportunity for Africa to gain energy access and energy independence, stimulate industrial growth and thereby reduce poverty. It is important to remember that reliance on the foreign transportation fuels and lack of electricity (less than 10% of rural population have access) are one of the major obstacles for economic and human development in Africa. Even though the biggest part of the energy needs in Africa are now satisfied by the primary bio-energy sources such as biomass and charcoal, the way of their use is often unsustainable and poorly efficient. Conversion of bio- and agricultural waste into fuels, such as biogas or biodiesel, as well as sustainable exploration of uncultivated lands for energy crops to produce bio-ethanol or biodiesel can significantly reduce the energy poverty in some regions.

It is useful to mention that traditional biomass (mainly wood and charcoal) is the dominant energy source in Africa, especially in Sub-Saharan Africa, which constitutes over a half of the total energy consumption of the continent (62% in 1995 and 49% in 2005 according to IEA) and is a primary source of energy for over 600 million people, mainly living in rural and the poorest areas. For example, the reliance on the traditional biomass energy in Tanzania is over 90%. It is well known that the traditional burning of wood biomass for heat generation is poorly efficient and non-sustainable, whereas its transformation into other forms of fuels and introduction of improved combustion practices helps to save a great deal of energy and natural resources, in addition to the diversification of the energy market.

Sustainable practices of biomass use in such regions, based on modern technologies and sound policies, should provide stable supply of local heat, power and transportation fuels with minimum social and environmental impact. Though it is expected that production of biofuels in Africa will further increase, to meet the demands of advanced countries and to avoid food crisis a sustainable resource management should be adopted, namely 1) increasing food production on current lands via introduction of more efficient agricultural practices; 2) establishment of bio-energy plantations, including large tree plantations, on low potential areas and degraded lands that are currently not used for food and use of modern forestry practices [1].

The abovementioned challenges can be realistically met in many African regions, where there are a number of strong advantages over other countries. One is a high percent of rural population. Second, over the total land area of 30.3 million of sq. km in Africa there is a plenty of uncultivated land (see maps in Fig. 1) with no need to deforest as the energy crops, e.g. Jatropha can grow even in semi-arid areas. With this potential Africa can double food production and produce biofuels too [2]. According to various experts, the biofuel potential of Africa is equivalent to 19% to 143% of the total primary energy supply in the continent. One problem that remains difficult to

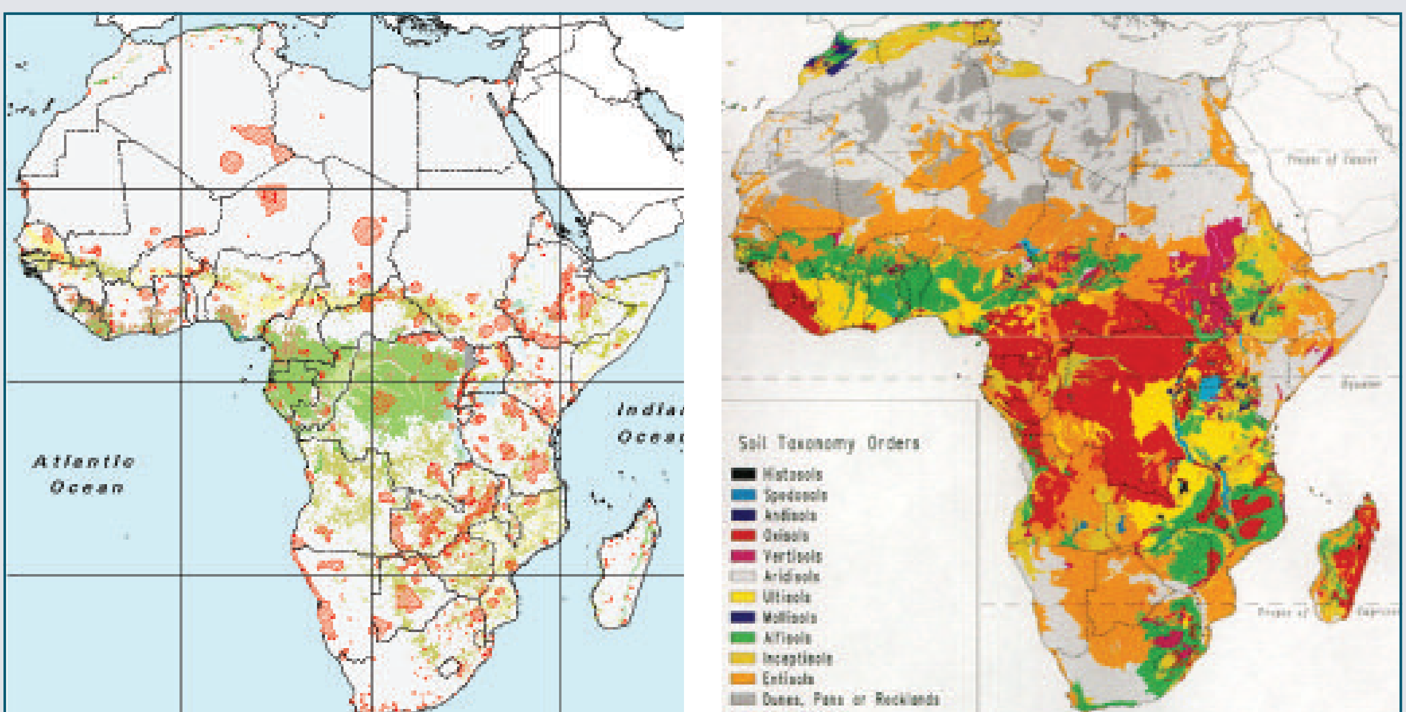

Fig. 1 - Africa's forested or protected lands (red and green spots on the left) and Africa's soil distribution by type (right) [2]

manage is water. Poor water supply, as well as generally retarded economic growth in Africa is owed mainly to the lack of infrastructure and transportation. With many people in the rural areas, as a rule, the poorest and distant from refineries and electricity grid, Africa pays more for fuel and electricity than in the industrialized countries. This is why there is a big advantage of integrating the local food and agro-industry with production of biofuel and other forms of renewable energy, which is to be done in a sustainable, balanced, and integrated way.

There are a number of obstacles hindering development of biofuels in Africa. In addition to the need to overcome social impact related to food competition and to adopt a sustainable resource management, significant obstacles relate also to financing and trading of renewable energy. However, besides these general issues which can be managed through the sound policy and regulation strategies, there are specific barriers affecting the deployment of biomass and other renewable energy technologies mainly due to their stage of development. For Africa, taking the lead in the biofuel and bio-energy market and taking advantage of its bio-resources needs first to build institutional capacity for efficient adaptation of technologies and for new technology development.

The challenge for many African countries that rely on traditional biomass is the adaptation of improved and modern technologies for biomass energy, including both aspects of energy use and biomass conversion to fuels and electricity. The simplest example is the successive introduction in many countries of the improved biomass technologies (IBT), such as cookstoves, woodstoves, charcoal kilns, and dryers which allow increasing energy efficiency two-fold in addition to lower in-door air pollution [3]. The advantages of IBT extend to more efficient biomass conversion technologies which reduce the negative deforestation impact of the traditional charcoal production. A very successful example is a project in Kenya driven by local input and international agencies, where the improved cookstoves (Kenya Ceramic Jilko) have been introduced to substitute the traditional stoves at 80% in the rural areas. Such stoves allow saving from 30% to 50% energy and are accessible (prices has reduced to 2 USD) to the poor population.

However, there is concern that vast reliance on the traditional biomass negatively affects the environment and economic development. To address the problem of deforestation many African governments promote the fuel diversification programmes, where in the first step, the massive shift to LPG as the more currently accessible fuel is expected. Though LPG is not a renewable fuel, its wide use will help to create a network and infrastructure for the further distribution of biogas which can be a realistic biofuel for Africa in the near future [1].

The modern biomass technologies address sustainable utilization of yet unexplored biomass sources, such as bio-waste and energy crops to deliver new forms of energy including biogas and landfill gas, combined heat and power, and liquid biofuels. Basic biogas technology is essentially simple and requires almost no infrastructure or large investments. Biogas facilities are accessible to small scale domestic use or for farm use where they allow to get rid of water pollution caused by animal waste. Waste-to-energy projects help to solve waste management problems of big municipalities. So far, there has been discrete success of the bio-gas programmes in some African countries. For example, in South Africa a landfill gas plant in Ethekwini generates 10 MW electricity for the city. In Tanzania, a biogas pilot plant was successfully realized and operated through a UNIDO project to yield 150 kW of electricity from the Sisal plantation's harvesting and processing residues, producing in addition a fertilizer. On the other hand, some small scale projects failed because of low operational experience and a lack of maintenance. Installation costs remain to be another problem. However, it is believed that the barriers can be removed with the proper educational and capacity building activities. A number of biogas projects in African countries are currently run by foreign companies and organizations including international agencies and support of local governments; the goal is to achieve several millions of biogas facilities in Africa in the next 10 years. According to some experts, the biogas potential in Africa is largely underexplored and is estimated to be 18.5 million domestic biogas units [1].

Biogas is a mixture of gases containing mainly methane and carbon dioxide obtained via the anaerobic digestion of organic matter. The usual feedstock for biogas production is various humid organic wastes, such as municipal or food waste, manure, maize silage, sewage sludge, etc. The technology is very simple: the organic waste is covered and isolated from oxygen, e.g. in a digester or a landfill where it is left for a period of time. Some sophisticated digesters can have temperature control and mixing/plug flow design. There are four basic types of microorganisms involved. Hydrolytic bacteria break down complex organic wastes into sugars and amino acids. Fermentative bacteria then convert those products into organic acids. Acidogenic microorganisms convert the acids into hydrogen, carbon dioxide and acetate. Finally, the methanogenic bacteria produce biogas from acetic acid, hydrogen and carbon dioxide. Advanced biogas technologies afford the 55-75% methane content in the producer gas. Biogas, after cleaning and drying can be fed into the power generation engine or be further upgraded (separation of CO_2) to bio-methane to substitute natural gas in the grid

Being the biogas a well developed and widely commercialized technology also in some developing countries, the issue of investment can be partially solved through strengthening commercial cooperation and experience exchange between Africa and these countries. This is the case of Niger where a number of biogas plants of Chinese technology have been installed, a programme supported by European Union, Chinese Government, and Canadian cooperation. In general, the cooperation of Africa with the emerging economies of India, China, Malaysia, and Brazil, or the so-called South-South cooperation, in the field of renewable energy technology often appears to be a viable way of new technology adaptation which is actively promoted by the UNIDO programme and by other international institutions (Fig. 2).

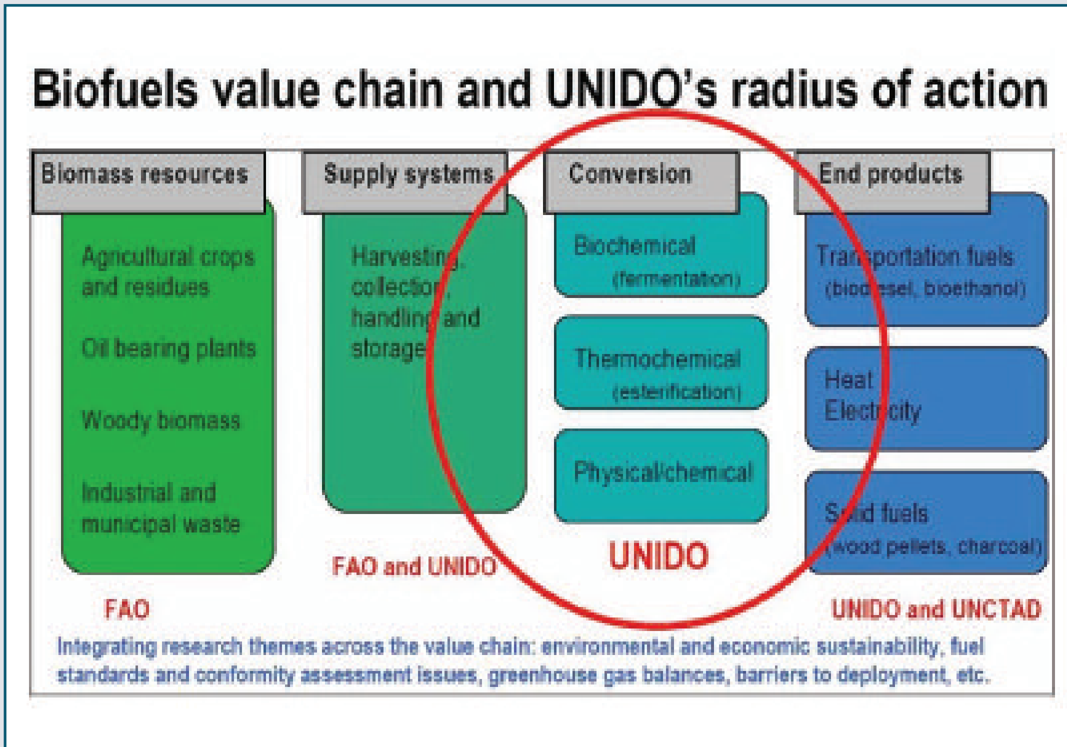

Fig. 2 - UNIDO's Biofuel strategy [5]

United Nations Industrial Development Organization (UNIDO) was instrumental in promotion of industrial development and transfer of new technologies in the energy sector in Africa and other developing countries and countries with economies in transition. The UNIDO Biofuels Strategy was developed in 2007 in order 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 Fig. 2). 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. Its activities spread from training, capacity building, and scientific divulgation to research in selected fields, including biofuel production processes. For example, ICS-UNIDO offers its expertise in development of Decision Support Tools for technology assessment and selection in order to enhance the technology transfer to developing countries by adopting an integrated approach which takes into account technical, social, economic, and environmental aspects of technologies and their applications [4].

Combined heat and power generation (CHP) also called cogeneration represents a thermodynamically efficient use of fuel. The by-product heat produced at a power plant is captured thereby allow gaining 30% of energy efficiency. The heat produced can be then used for domestic or industrial purposes. Cogeneration plants have been widely used in large cities to provide electricity and hot water from fossil fuels. The new CHP concept is based on the use of biomass, especially bio-waste, as a fuel and it opens up promising opportunities for African agro-industries, such as wood industry, rice mills, palm, and sugar producers. The potential of producing electricity from sugar waste (bagasse) in Eastern Africa represents a significant portion of the total installed national power generation, sometimes even higher like in Swaziland; however, this potential is often underexplored. A useful example is Mauritius where over 40% of total national electricity needs come from the cogeneration with half of this coming from bagasse. In South Africa the cogeneration yields nearly 10% of national installed capacity (Tab. 1).

It is notable that the modern cogeneration plants are usually installed at the ethanol production facilities. Ethanol or bioethanol is probably the most developed biofuel in Africa and can be produced from sugarcane, corn, cassava, and sweet sorghum via the known and accessible sugar and starch

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Tab. 1 - Potential and currently installed cogeneration capacities in some African countries

Country	Potential at 150 kWh/tons, MW	Currently installed, % of potential
Kenya	159.2	14
Ethiopia	32.4	4
Tanzania	102.6	11
Sudan	16	21
Malawi	59.2	24
Swaziland	194.0	145
Uganda	48.3	15

Tab. 2 - Ethanol potential from cane in selected Sub-Saharan Africa countries

Country	Cane crushed (2002), tons	Ethanol production potential (2002), x103 L
Kenya	5,904,108	413,288
Sudan	5,821,000	407,470
Tanzania	3,628,800	254,016
Malawi	2,095,065	146,655
Ethiopia	1,147,283	80,310
Uganda	1,707,000	119,490
Swaziland	6,861,600	480,312
Source: [1]		

fermentation technology. Molasses coming from sugar mills are also a common feedstock. To mention, the practices of industrial scale ethanol production for fuel use as a mixture with gasoline in motor vehicles in Zimbabwe, Malawi, and Kenya date back to 1980s, initiated due to the high oil prices in 1970s and no oil reserves in these countries. Other African ethanol producers are Zambia Swaziland, Mauritius, Ethiopia, and South Africa. However, bulk of ethanol produced in Africa is currently destined to chemical and pharmaceutical industry. Comparing to the 74% of the global ethanol production by the leading US, Brazil, China, only 1% is contributed by Africa which is restricted mainly to production in Southern Africa (nearly 70% of Africa's total ethanol production) while in other countries the ethanol potential remains for the main part undisclosed.

Tab. 2 shows the potential of ethanol production from sugarcane waste based on the existing cane industry capacity and estimated an average of 70 L ethanol per tone of cane crushed. With this potential coupled with a long standing experience and recent advancements in the ethanol production technology, including also the second generation bio-ethanol produced from lignocellulose (agro-, and forestry waste), it is believed that the ethanol industry can become very efficient in many African countries. In Kenya, for example, the recently revived ethanol plant privatized by Energem (Canada) is currently producing nearly 60,000 liters per day ethanol and is expected to yield 250,000 lpd in the future.

Bio-ethanol for fuel application is produced essentially using the same well known technology as the ethanol for beverages, i.e. via the microbial (yeast) fermentation of sugars extracted from crops such as sugarcane, sugar beet, etc. In the case of starch which can be obtained from corn or potato it should be hydrolyzed to simple (C6) sugars via enzymatic hydrolysis before the fermentation step. Successive stages include distillation and purification of the product. Anhydrous bioethanol can be blended with gasoline in different proportions, usually up to 10% as this blend does not require engine modifications. Bioethanol is an environmentally benign fuel as it contains oxygen and thus is more easily oxidized and yields less CO, hydrocarbons, and particulate, than e.g. traditional gasoline fuel from petroleum.

Biodiesel is still in the embryonic stage of development in Africa where the related initiatives are limited to rather demonstration initiatives and pilot experiments than true production. A number of successful examples of the production and use of vegetable oil based fuels exist in many countries, only some of them are Malawi, Zambia,

Fig. 3 - Jatropha Curcas (left) - the Africa's leader in biofuel race. Perkins engine (middle) with generator converted to run on Jatropha oil, is now installed in Kumasi, Ghana [6]. The Jatropha energy platform concept installed in villages in Mali - a multifunctional machine powered by Jatropha oil which combines generator, charger, oil press and mill [7]

Madagascar, Mozambique, South Africa, Tanzania, Kenya, Uganda, Mali. However the biodiesel practices are mostly limited to cultivation of oil crops and vegetable oil extraction. The crops that can be cultivated for oil use as a fuel include soybean, sunflower, oil palm, and Jatropha, the latter is probably the most important in Africa due to its resistance to harsh climate conditions. Jatropha can grow on infertile soils and animals do not graze on it; it can be cultivated in degraded and marginal lands not affecting food production (Fig. 3). Oil extracted from *Jatropha Curcas* seeds possesses excellent fuel characteristics and can be used as is in power generators or even in motor vehicles (significant experience on jatropha oil use as a fuel exist in Mali) or be upgraded through conversion to bio-diesel via the transesterification technology. The latter is still a technically challenging and not yet economically viable option for most African countries, where only few demonstration and pilot transesterification plants exist.

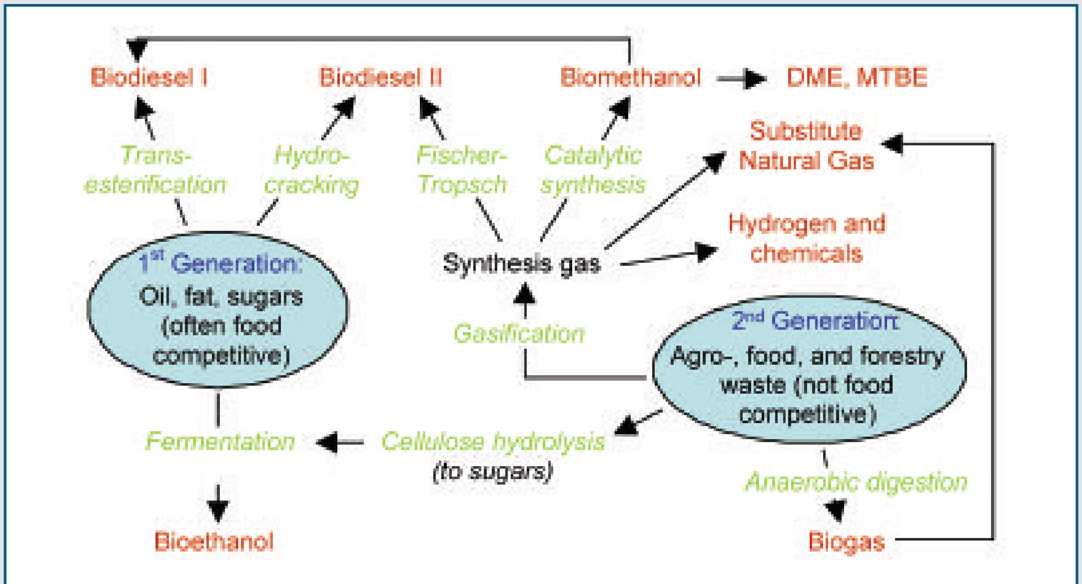

Fig. 4 - Schematic overview of chemical pathways of biomass exploitation for production of the biofuels of 1st and 2nd generations

In the prospective, biodiesel from Jatropha can be easily produced also on the small scale, e.g. in the rural areas thereby providing secure fuel supply for farmers. Besides the issue of competition of biodiesel production with food industry, one of the major obstacles for biodiesel market development remains its higher price than petroleum (min 0.4 USD per liter, e.g. compared to min 0.25 USD per liter of bio-ethanol). Nevertheless, there is always increasing potential for growth through research and development due to the continuous increase in the petroleum prices (Fig. 4).

Transesterification is a chemical reaction whereby the fatty acids present as fragments of the triglyceride molecule of vegetable oils or fats are coupled with methanol to produce methyl esters of fatty acids (biodiesel) and glycerol (by-product). The reaction occurs upon mixing of oil, methanol and a catalyst at some elevated temperature. The obtained methyl esters, the so-called biodiesel of the first generation, possess better fuel properties than the original oils, mainly due to lower viscosity, higher flash point, and less damage to engine caused by incomplete combustion. Generally the advantages of biodiesel over the traditional diesel lie in its better lubricating properties, higher cetane number, lower sulphur content, and biodegradability, and less contamination because of its better combustion (biodiesel is an oxygenated fuel like bioethanol). Biodiesel can be mixed in any proportion with the petroleum diesel; even at small addition it significantly improves lubricating properties of the fuel.

The second generation biofuels, contrary to biodiesel and bioethanol of the first generation - biofuels produced from energy crops like sugar and oily crops, rely mainly on yet unexplored bioresources such as lignocellulose and biomass wastes. A range of technologies (see Fig. 4) are currently in intense development for production of the second generation biofuels, from the pyrolytic biomass conversion and catalytic Fischer-Tropsch synthesis (BtL diesel) to the advanced methods of wood hydrolysis (lignocellulosic bioethanol). A great deal of R&D is concentrated on lignocellulose hydrolysis, e.g. using new enzymatic processes, heterogeneous catalysts, etc. Another approach, gasification of biomass to synthesis gas, opens up many possibilities as the synthesis gas can be further converted to a range of fuels and utility chemicals. The ultimate scope of this development is the possibility to valorize almost any type of organic matter, mainly agro- and forestry waste. Vast development and demonstration of the second generation biofuel production technologies is hampered by their weak economic viability, especially for low scale production.

No full scale operating plants for second generation biofuels in Africa exist so far. The only workable concept appears the small scale biomass gasification to produce synthesis gas for power generation; however, even this simplest concept has met technical difficulties and is not yet affordable for wide commercial application. A few demonstration studies on gasification for power generation have been implemented with variant success, e.g. 200 kW gasifier has been in operation in Uganda. As in the developed countries the second generation biofuels still require time for the technology to be competitive; yet, in Africa significant additional barriers are connected with a lack of infrastructure, human capacity, to make commercial second generation biofuels economically viable.

Tab. 3 - Comparison of job creation - Biomass and conventional energy forms

Sector	Jobs-person-years
Petroleum	260
Offshore oil	265
Natural gas	250
Coal	370
Nuclear	75
Wood energy	1,000
Ethanol from sugarcane	4,000

Source: [8]

Besides the environmental and sustainability issues, the development of biofuels in Africa has a significant social impact as it contributes to reduction of poverty through rural development and job creation in the region where in most countries the levels of under- and unemployment are desperate. Occupational needs of the biomass sector are of the highest in the energy industry as exemplified in Tab. 3.

In conclusion, taking into account the abovementioned potentials and opportunities a clear message appears to be the importance to mobilize cooperation and political will in the frame of biofuels and bio-energy technology in Africa. To assure the efficient implementation of biofuel and bio-energy technology adaptation programmes, an integrated approach has to adopted to bring together necessary R&D activities, education, capacity building, public awareness, and sound policy and regulation of the biofuel market. It is also important that an integrated resource management be promoted as well, based on the potentials of specific countries and basic sustainability principles.

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