



BIOENERGY STRATEGY

**Sustainable Industrial Conversion
and Productive Use of Bioenergy**



UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

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1. Introduction

At a time of rapidly rising world energy demand and high oil prices the production and use of bioenergy has entered a new era of global growth, with both the scale of the industry and the number of countries involved reaching unprecedented levels. Underlying the growing commitment of governments to bioenergy development are not only economic but also environmental and social factors: Apart from enhancing energy security, bioenergy is considered a “cleaner” alternative to fossil fuels, reducing emissions of carbon dioxide and other gases that are contributing to global warming, and it can provide new markets for farmers and their products, thereby providing employment and increasing social welfare.

However, there is also growing realization that the production of bioenergy on the scales necessary to supply significant shares of national and global energy provision will result in very substantial impacts (positive as well as negative) on the ecosystems, economies and cultures of the target regions. The protection of biodiversity, rural livelihoods and management of scarce water resources are critical considerations in any analysis of the potential for sustainable bioenergy provision in any country. Therefore, whilst modern bioenergy could contribute significantly to poverty alleviation in rural areas, the effects of changes to the supplies of natural resources and ownership of those resources are of concern to policy makers.

Modern bioenergy refers to biomass that may be either burned directly, further processed into densified and dried solid fuels, or converted into liquids or gaseous fuels using so-called first- or second-generation technologies, depending on their level of development.

This bioenergy strategy was developed in response to increased interest by UNIDO’s client countries for support to national bioenergy strategies and programmes. In order for UNIDO’s governing bodies to decide on the level of UNIDO’s involvement in this subject area it was considered imperative to establish a process by which a comprehensive assessment of all factors influencing the implementation of bioenergy programmes in developing countries is undertaken, and a clear strategy is developed.

In 2006, UNIDO, with the assistance of a renowned research institute, set up a bioenergy task force to prepare a document, which would summarize global bioenergy developments, initiatives by international, bilateral and other UN agencies and identify potential areas for UNIDO’s intervention. This document was discussed internally with UNIDO’s technical staff and at an international meeting with energy experts from developing countries as well as representatives of UN partner agencies, research institutes and donor governments. The outcome of all those consultations was compiled into a final strategy outlining UNIDO’s position in the bioenergy discussion.

The discussion on bioenergy is very dynamic, contentious and complex. Within and outside of UNIDO many different standpoints and convictions exist, which needed to be discussed, analysed and coordinated to provide an acceptable and comprehensive framework for a UNIDO bioenergy programme. In 2007, this process of developing a bioenergy strategy was deepened and involved a wide segment of UNIDO’s staff and experts. At the same time, new publications were released, some of which bear great relevance for UNIDO’s work on bioenergy, such as the UN-Energy paper on Sustainable Bioenergy: A Framework for Decision Makers (UN-Energy, 2007).

UNIDO is a very active member of UN-Energy, which is a collaborative framework for all UN bodies that contribute to energy solutions. Therefore, this bioenergy strategy takes into consideration recommendations expressed by UN-Energy to be able to propose a multi-disciplinary, integrated and focused approach to delivering a UNIDO bioenergy programme.

This strategy focuses on modern bioenergy, which includes liquid biofuels, biogas, and solid biomass for heat and power generation. Yet, it needs to be acknowledged that traditional use of bioenergy is an important source of energy in developing countries, where on average a third of all primary energy comes from biomass, in some African countries, even up to 90%. The energy supply of approx. 2 billion people depends nearly exclusively on traditional use of bioenergy, usually in the form of inefficient direct combustion of firewood or dung, mainly used for cooking (Karekezi 2004) at the household level. The focus of UNIDO’s intervention is, however, on industrial applications and productive uses of modern bioenergy.

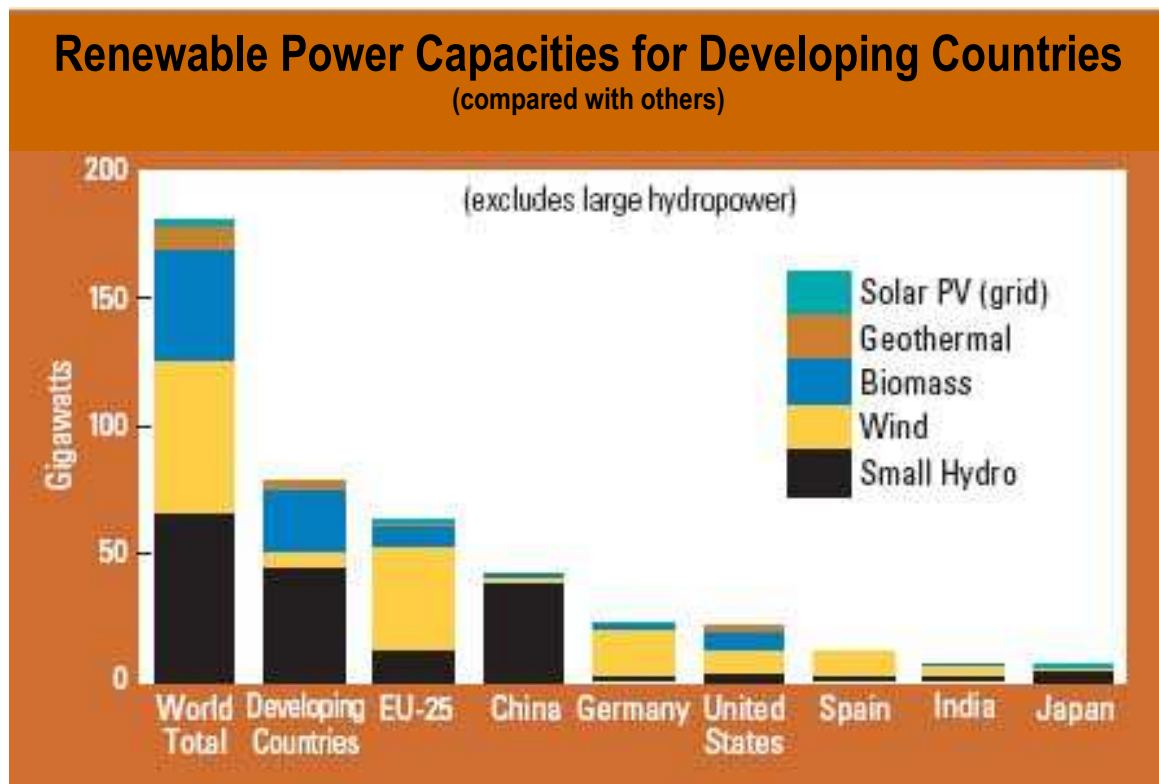
2. The Need for a Bioenergy programme at UNIDO

a. Context

For the world's poorest households, basic energy services for cooking and heating, lighting, communication, water pumping, and food processing are particularly important. Shifting these basic energy uses from traditional bioenergy (when used in unsustainable and health-damaging forms) to **modern fuels and electricity** is probably one of the most important and long-lasting challenges.

UN-Energy, 2007

The major share of today's human consumption of biomass is dedicated to the provision of food, animal feed, and biomaterials (mainly fiber, and timber for construction). Currently, only about 10 percent of the biomass is used as bioenergy, but residues find their way into cooking stoves, furnaces, and power plants. All forms of bioenergy supply about 10 percent of the world primary energy demand, representing 90 percent of the global contribution of all renewable energies (REN21, 2006).



Source: REN 21/ IEA/ UNEP

Future prospects

Forecasts show that in the most optimistic scenarios, bioenergy could provide for more than twice the current global energy demand, without competing with food production, forest protection efforts, and biodiversity. In the least favorable scenarios however, bioenergy could supply only a fraction of current energy use, perhaps even less than it provides today. This significant range of uncertainty of the sustainable global bioenergy potential is a consequence of the uncertain developments in future agricultural and land use policies, especially in developing

countries. Factors such as increases in productivity could free the land for bioenergy crops, and conversion of marginal and degraded land into bioenergy production areas could expand the resource base as well. On the other hand, impacts from climate change such as heat waves and droughts, as well as competing uses of land (food, nature conservation) could severely restrict the future bioenergy potential.

Food vs. fuel

A key concern in the global bioenergy discussion is the competition between land-use for bioenergy production and food and animal feed production. If there is no direct competition it could show indirectly through economic (price) feedbacks as can be seen in recent sugar and corn price fluctuations. This competition has a special significance insofar as food security is concerned, and the MDGs clearly require policies to reduce hunger, and increase food security. In this respect, a switch to large-scale bioenergy production might have indirect adverse impacts on food security, which need further attention. As long as bioenergy mainly comes from plants which can be also used for food production, the economic effects of coupling the energy (i.e. bioenergy) market with food markets could increase food prices, and – hence – worsen the access to affordable food for many. The indirect effect of increased prices for traditional agro-products, however, could increase farmer (and country) income, and thus help increase food security, depending on the distribution of the increased income. As the overall outcome of such developments is still being debated, the FAO announced recently to research the food-versus-fuel issue in more detail (FAO 2006b). The outcome of this research should be considered key in safeguarding future bioenergy development against food competition.

Economic competitiveness

Concerning economic competitiveness of bioenergy, already today, heating applications based on modern bioenergy can compete with oil and gas, and electricity generation with biogas from residues, landfills, or wastewater treatment undercuts costs of oil- and gas-fired power plants. Ethanol from sugarcane in Brazil is competitive without subsidies at 35-50 US\$/bbl oil (WB 2005), while most other liquid biofuels for transport need further development before becoming economically attractive at oil prices in the 50 US\$/bbl range. Yet, volatility in oil prices could also endanger investments in market introduction of biofuels.

Trade implications

International biofuels trade is an issue for global players, with SMEs having a minor role so far. As a consequence of the energy price and supply security developments, however, interest in global trade of biofuels is spreading. Since the mid-1990s, biomass trade flows increased rapidly, partly as a result of reduced marine bulk transport cost. Many trade flows are between neighboring countries, but long-distance trade also occurs, for example, with export of ethanol from Brazil to Japan and the EU, palm kernel shells from Malaysia to the Netherlands, wood pellets from Canada to Sweden. Nearly all of that trade is across waterways, or uses large maritime cargo vessels. The IEA Bioenergy Task 40 projects a significant increase in global shipping of biomass products in the next years.

In addition, the failure of the WTO Doha Round in opening agricultural markets of OECD countries (and to restrict subsidized agricultural exports) shifts the focus of traditional farming from cash crops to dedicated bioenergy crops, which have the prospect of higher revenues on international markets if converted into biofuels.¹

Sustainability issues

With the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg, and the formulation of the Millennium Development Goals (MDGs)², sustainable development in general, and its link to energy became prominent issues in global fora. In this context, there are currently many national and international initiatives underway to safeguard against negative social and environmental impacts of future bioenergy developments. Concerns over land use (as referred to in the food vs. fuel discussion), land ownership, loss of biodiversity and

¹ Market access and differences in tariff structure are another cause. Furthermore, biodiesel is regarded as an industrial product, whereas bioethanol is treated as an agricultural product and, therefore, faces higher import duties.

² Although there is no specific MDG relating to energy, the MDGs cannot be met without affordable, accessible and reliable energy services (UN Energy 2005).

genetically modified organisms (GMOs), greenhouse gas emissions, soil erosion and other soil degradation, water use and water contamination, human health impacts, labour conditions and rights of children are all part of the sustainability discussion and international efforts to formulate standards.

Climate change

Bioenergy could, in comparison to fossil fuels, drastically reduce Greenhouse Gases (GHG) and air emissions, if managed adequately. However, there are many factors to be taken into account when quantifying GHG emissions. Current knowledge of GHG balances of bioenergy indicates a rather large range (Larson 2006). For specified regions like the EU, quantification is possible with regard to the different bioenergy crops, conversion routes, and by-product utilization rates (OEKO, 2006). For other regions like the USA, and a few developing countries (Brazil, China, India), some data on the life-cycle GHG balances exist, while other countries like Thailand have ongoing research programme in that area.

Technology transfer

Realization of the potential of bioenergy depends to a great extent on the availability of competitive conversion technologies. Yet, these technologies are not readily available in developing countries.

The bioenergy field is experiencing an unprecedented wave of research and development, flowing from both the public and private sectors. The timing of commercialization is uncertain, but those countries that have begun to develop bioenergy industries may be the most likely to attract investment and benefit from the resulting technology transfer.

UN-Energy, 2007

To this end, there is a need for support mechanisms that would encourage the transfer of relevant technologies and associated capacities from technology producers to technology markets. Since UNIDO's focus will center on providing such support mechanisms the following sections will describe the current situation with regard to existing and future conversion technologies³:

Bioenergy: Electricity and Heat from Biomass

The conversion of biomass to energy is quite a traditional human activity – from the fire used in pre-historic times to modern cooking stoves⁴, and electricity generation from biogenic residues burnt to generate steam for backpressure-turbine power plants.

1. Production of Marketable Fuels

Over the last years, pre-processing of biogenic wastes (e.g. chipping, compaction, fermentation, pelletization) was developed to commercial-scale applications, so that wood chips and pellets are now common commodities. Similar developments now occur for other biogenic residues (e.g., coconut shells, rice husks), so that the existing resource base for solid biomass residues and wastes becomes available for interested customers – both in the neighborhood of the source, but through modern logistics and trade also on a global scale.

2. Gasification of Solid Biomass

Countries like India have developed smaller-scale gasification of solid biomass, so that process heat and electricity from solid bio-waste can be generated more cost-efficiently in internal combustion engines (ICE). There is a future potential of biomass-integrated gasification (BIG) coupled with micro-gas turbines (BIG- μ GT) and – in the longer run – with solid-oxide fuel cells (BIG-SOFC) to enhance electricity conversion efficiency, and reduce operating costs of cogeneration.

³ For a comparison on bioenergy conversion technologies with regard to costs a separate full report to this strategy document is available.

⁴ It should be noted that modern biomass use for cooking is also an issue on the household level (e.g., through efficient stoves, biogas, ethanol-based gelfuels). As this report is mainly concerned with biomass applications in the industrial sector, these technologies will not be discussed any further.

A remaining challenge for medium-to-large-scale process heat and electricity generation is the coupling of high-capacity gasification schemes for biomass with steam-injection gas-turbines (STIG), or combined-cycles (CC). This biomass-integrated gasification (BIG) was demonstrated with (circulating and pressurized) fluidized-bed technologies, and is under development for entrained-flow gasifiers as well. Various R&D activities in IEA countries as well as the CHRISGAS project⁵ of the EU, and national projects in Austria, Denmark, Finland, and Japan. The Netherlands, Sweden, the UK, and the US aim at optimizing the gasification process, hot gas cleaning, and overall process integration to increase efficiency, and reduce investment and operating costs. The technology development of medium-to-large-scale gasification is assumed to benefit from the rising interest and R&D efforts in so-called clean-coal, and in the gasification routes of the 2nd generation biofuels.

3. Technology Perspectives for Electricity and Heat from Biomass

With respect to future market potentials, smaller-scale bioenergy cogeneration systems are, depending on fuel costs and revenues from cogenerated by-products, already competitive with fossil-based generation, or close to becoming so. Interestingly, the market introduction of such technologies is developing far more rapidly in developing countries than in industrialized ones. With the increased availability of liquid biofuels, small-scale cogeneration with diesel engines using liquid biofuels (SVO or FAME) as inputs become attractive additional options, especially for stand-alone and mini-grid applications in developing countries as well as for “green” electricity generation in industrialized nations (e.g., The Netherlands).

Medium-to-large cogeneration using bioenergy is already in the market, and could benefit from the BIG developments, especially for industrial process heat, and onsite cogeneration. With “hybrid” schemes and “biorefineries” for multiple outputs becoming available in the next decade power and fuel markets might well overlap or even merge, allowing the bioenergy industry to optimize their outputs according to market development and revenue opportunities.

With the emerging bio- and thermochemical conversion systems for bioenergy the bioenergy power and heat sector will be coupled more closely to the transport sector. Indirectly, this will also couple the commodity prices for traditional agricultural and forestry products with the energy sector. This development would mean that the “traditional” agro- and forestry product industries will have to consider the developments in the (bio)energy and (bio)fuel markets far more closely, and even could decide to be active in those markets.

Liquid Biofuels for Transport: The 1st and 2nd Generation

As an alternative to electricity and heat supply, biomass can be converted also into liquid biofuels to replace fossil gasoline, and diesel in the transport sector.

“First-generation” fuels refer to bioenergys made from sugar, starch, vegetable oil, or animal fats using conventional technologies. “Second-generation” fuels are made from lignocellulosic biomass feedstock using advanced technical processes.

However, costs of biofuels need to be compared with those of their fossil fuel equivalents in order to identify whether cost competitiveness is given at each level of production and within the given time horizon: Expected yields, feedstock costs, interest rates, and cost of workforce are important factors, and dynamic effects such as scale and learning effects, but also economic feedbacks from agricultural markets, land use policies, and oil prices need to be taken into account.

All forms of biomass have alternative uses. Infrastructure requirements might also add to the cost of biofuels. Smaller, poorer and/or landlocked developing countries face the highest costs due to smaller scale operations, lack of market access, and under-developed infrastructure. These factors limit the commercial viability of potentially cheap feedstocks.

⁵ This project is based on the successful operation of the Värnamo wood gasification demonstration plant in Sweden. The plant was converted into a research platform for bio-hydrogen, and more R&D is carried out on fluidized-bed gasification. For more details, see www.chrisgas.com.

1. First-Generation Biofuels

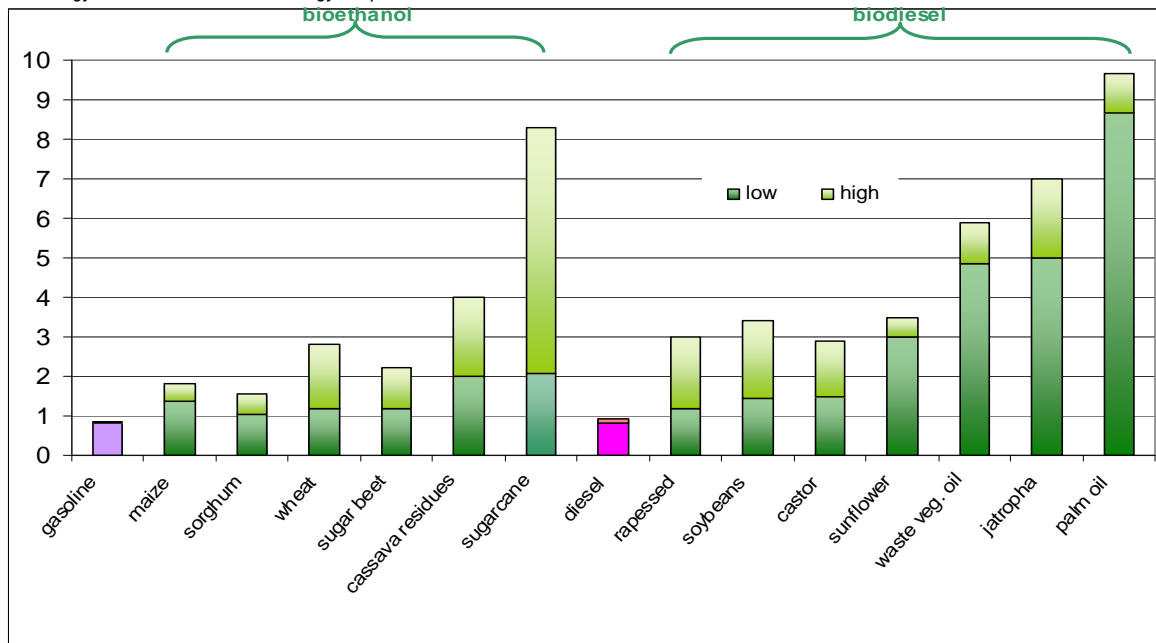
Ethanol from biomass as a substitute for gasoline is currently the dominating biofuel on the global scale. Suitable biogenic feedstocks contain high shares of sugar or starch, which is catalyzed into simple sugars and then fermented into ethanol. Sugar cane in particular is the feedstock that already provides a large amount of ethanol in Brazil. Other crops, which can be converted into ethanol are cassava, maize, sorghum, and wheat. Other feedstocks for 1st generation ethanol are potatoes, and sugar beets. The conversion of their starch content into sugar has a high energy demand, so that the cost of the product is quite high.

Ethanol from fermenting starch- or sugar-rich plant material is called “1st generation” because it already exists, has proven efficiencies, and well-established economics. For starch-based ethanol, costs further depend on the revenue from byproducts⁶. Other than residue utilization and economies of scale, few options for further improvement exist.

Oilseed-yielding plants like castor, cotton, jatropha, palm, rape, soy, etc. offer a feedstock from which straight vegetable oils (SVO) can be derived by physical and chemical treatment (milling/refining). The SVO can then be processed further into fatty acid methyl esters (FAME), also known as biodiesel. Similar to ethanol, these routes are established and proven, and their costs depend heavily on two factors, a) costs of the feedstock (> 90 percent for SVO, some 85 percent for FAME), and b) revenues from by-product utilization (cake, glycerin). Another route for biodiesel is to “hydrotreat” unprocessed bio-oils (from castor, cotton, palm, soy etc.) so that no transesterification is needed to stabilize the biodiesel.

The net energy yields of bioenergy crops used for 1st generation biofuels are given in the following figure, in which all in- and outputs are considered, i.e., agrochemicals, by-products, and auxiliary fossil energies⁷.

Net Energy Yield Factors from Bioenergy Crops, and Fossil Fuels



Source: adapted from WWI/gtz (2006); data gives the ratio of energy output per unit of fossil energy input

⁶ The two common methods for refining starches into sugars differ primarily in the feedstock pre-treatment, and by-products: *wet* mills co-produce a variety of products while *dry* mills grind heterogeneous seed into granules, requiring less investment, producing fewer co-products. Wet mills co-produce corn oil, gluten, germ meal, starches, dextrin, and sweeteners such as high fructose corn syrup. Sold mostly as processed foods and feeds, these products together comprise more than one-quarter of a wet mill's economic output. The primary co-product of dry mills is DDGS which provides some 20 percent of the dry mill revenue. Because they produce a variety of products, wet mills already are called “biorefineries”.

⁷ Note that farming practices such as reduced tilling, use of organic fertilizers etc. could significantly change the net yield ratios.

For developing countries it is potentially valuable that 1st generation biodiesel can also be derived from plants like *Jatropha*, which show comparatively low yields, but need only minor inputs so that their overall costs might be moderate if land and labor costs are low. *Jatropha* can be grown on marginal and even degraded land, and needs only little irrigation during the first years. As regards 1st generation ethanol, feedstocks like cassava or sweet sorghum might be interesting⁸.

2. Second-Generation Biofuels

The existing 1st generation biofuels give positive energy returns, but oilseed and starch crops⁹ require indirectly 30 to 50 percent of their yield as fossil fuel inputs. The biofuels themselves are CO₂-neutral when burnt, but their life-cycle (seeding, farming, harvesting, conversion, and agrochemicals and fossil fuels needed to operate bioenergy cropping systems) are the cause of GHG emissions.

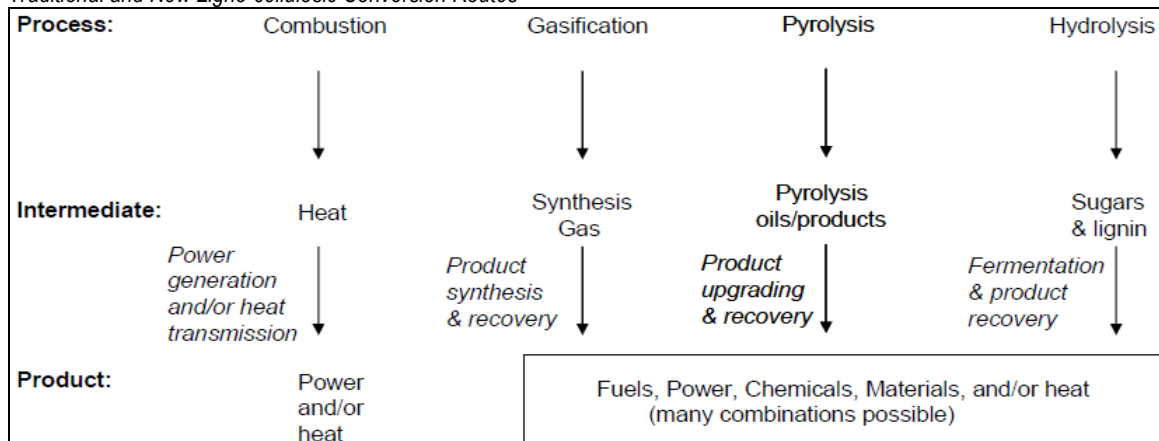
In the last decade, other options for biofuels were researched, and two new conversion routes are currently in the pilot stage – but still far from commercial operation. These next or 2nd generation biofuel technologies differ fundamentally in their technology, but are similar in two ways:

- To extend the biofuel yield, the whole plant material is to be used as a feedstock.
- The feedstock is to come from “non-food” perennial crops (in principle woody biomass and tall grasses) and lingo-cellulosic residues and wastes (e.g. woodchips from forest thinning and harvest residues, surplus straw from agriculture).

Cellulosic biomass from fast-growing perennial crops such as short-rotation wood and tall grass crops can be grown on a wider range of soil types than 1st generation feedstocks (some even on marginal or degraded land), and require less agrochemical inputs. Furthermore, the root systems of perennials remain in place after harvest so that these crops, compared to annual ones, reduce erosion, and could increase carbon storage in soil. However, high biomass yields will only be achieved on good soils with sufficient water supply.

Cellulosic biomass as feedstock is quite promising, but the plant material is far more difficult to break down and convert to liquid fuels than conventional sugar, starch and oilseed crops. The following figure shows the general routes to process whole-plant materials or biogenic residues into various products.

Traditional and New Ligno-cellulosic Conversion Routes



Source: WWI/gtz (2006)

New conversion pathways for lignocellulosic plant materials:

⁸ For example, research in Thailand indicates moderate prospects for future cassava-based ethanol (JGSEE 2006).

⁹ The exceptions are sugarcane and palm where the plant material not converted into biofuels is used to “drive” the conversion process (e.g. process heat). Furthermore, these plants grow only under specific climate and soil conditions, and need high precipitation rates (or costly irrigation). These factors restrict the land to grow palm and sugarcane and hence, their overall bioenergy potential.

- *The Biochemical Route: Lignocellulosic Ethanol from Hydrolysis*
One of the two next generation biofuel technologies options is to upgrade existing processes of fermenting sugars by using enzymatic-enhanced pre-treatment of (hemi)cellulose. This route requires genetically modified organisms to provide for the needed enzymes, and sophisticated process controls.
- *The Thermochemical Route: BtL*
Other next generation option is to completely break down biomass by means of thermal gasification, then to synthesize biofuels using the Fischer-Tropsch process. This route is called “biomass-to-liquid” (BtL).
- *Competitors: Pyrolysis, HTU, and More*
Other RTD efforts for new biofuels focus on pyrolysis, including “flash” or “fast” processes for wet biomass without pre-drying. Similar efforts concentrate on hydrothermal upgrading (HTU). Other research is aiming to convert solid biomass more or less directly into a natural-gas equivalent called substitute natural gas (SNG), while some even target hydrogen (H₂) as the key output product.

3. Biogas as an “in between” Biofuel

Biogas can also be upgraded to SNG, so that it can be fed into existing natural gas pipeline systems (both locally, nationally, or even for cross-border trade), or further compressed so that it gives a “green” CNG, which can be used in gas-engine vehicles (buses, cars, trains, trucks etc.). Biogas can further be processed into a green GtL (gas-to-liquid), thus becoming directly available as a powerful and very clean-burning liquid fuel.

Biogas – at least in Europe - has developed in the last years far beyond the mere fermentation of “messy” biomass residues like dung, liquid manure, or organic household wastes: nowadays, it can be derived from modern bioenergy crops such as maize (or corn), wheat, and even more interestingly from mixed or double cropping farming systems, which can integrate various old plant varieties into their rotation and give net energy yields comparable to the best palm oil, or sugarcane plantations. In comparison to 2nd generation biofuels, biogas further offers nearly closed nutrient cycles, and can make use of more or less all plant nitrogen endogenously, so that chemical fertilizers are not needed.

Hybrid Bio-conversion Concepts

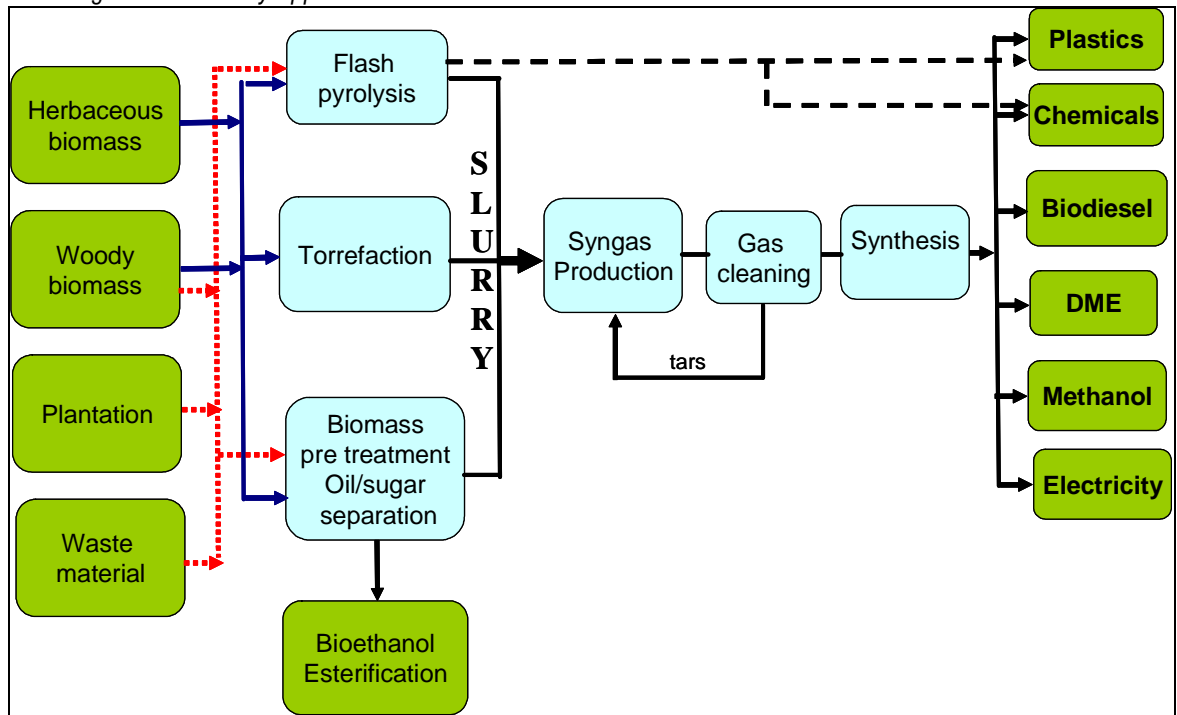
The distinction between biomass for electricity and heat on the one side, and biofuels for transport on the other is becoming more and more obsolete as technologies for feedstock conversion evolve and 1st generation liquid biofuels are used also in traditional power and heat markets. Before fully considering complex conversion options like biorefineries it should be noted that combinations of 1st and 2nd generation conversion routes, and technological coupling of biofuel and electricity conversion (“hybrids”) are potential options in the near future: instead of optimizing for one output, the relative strength of each route can be brought together into a synergized (or hybridized) new configuration with higher overall efficiency.

Biorefineries

Biomass both from residues/wastes and dedicated crops can be converted not only to bioenergy (electricity, heat) and biofuels for transport, but also to bulk chemicals or materials which are nearly equivalent to those derived from fossil hydrocarbons.

The concept of a biorefinery aims to optimize the conversion of biomass feedstock so that its output mix reflects the highest revenues, and covers all attractive markets. The overall concept is shown in the following figure:

The Integrated Biorefinery Approach



Source: Girard/Fallot (2006)

As with the 2nd generation biofuel technologies to which biorefineries are closely related it is currently not possible to know with any certainty how future biorefinery concepts will perform, what they will cost, and which products they are going to deliver to the market. The concept is promising insofar as oxygenated chemicals become more prominent and biochemical conversion knowledge is benefiting from developments in industrial biotechnology.

Still, biorefineries will not be off-the-shelf systems, nor small-scale neighbouring plants: quite contrary, their complexity will be high, and to become competitive, their size will be in the order of some thousand MW_{th} equivalent, thus resembling their fossil name-relatives. Infrastructure needs will be accordingly high, and their most probable way of becoming a reality will be as an “offspring” of 2nd generation biofuel plants.

However, the overall biorefinery technology paradigm is important as it indicates the willingness to consider biomass in all potential areas of application. In the future, the biorefinery paradigm might foster spin-offs suitable for smaller-scale application.

b. [Potential of bioenergy for developing countries: current and future situation](#)

The review of key issues presented in the previous context section clearly shows that bioenergy development is very complex and dependent on local circumstances such as climatic, agronomic, economic, and social conditions. Therefore, it is prudent not to generalize about the efficacy of particular approaches. Yet, this complexity of issues should not restrain action, particularly since “the movement towards more sustainable energy systems that draw from all potential renewable sources, including bioenergy, is a matter of urgency”(UN-Energy, 2007)

The UN-Energy paper on bioenergy has identified key areas, which should be addressed, at the national and international levels. A framework for decision-makers is suggested which aims “to encourage the sustainable production and use of modern bioenergy in order to achieve maximum benefits to the poor and to the environment”. In the following the recommended actions are summarized in tabular form (UN-Energy: Sustainable Bioenergy, Section 4):

NATIONAL LEVEL	
At the national level, knowledge and policies are key in providing and sustaining a solid base for action in the bioenergy field.	
KNOWLEDGE	This set of information and knowledge is the backbone to decision-making since it provides the physical, social, and economic basis for action (which requires regular up-dating)
	Resource base
	Current production of agricultural products with bioenergy potential, as well as assessment of possible energy use and expansion of production;
	Current land uses, obtained with the help of surveys, mapping, and GIS;
	Production potential in rehabilitated marginal and degraded lands;
	Alternative uses of feedstock as well as current demand and uses of agricultural and forestry residues and by-products;
	Availability of water and other resources.
	Technologies
	Availability and accessibility of modern technologies for bioenergy conversion and use;
	Life-cycle analysis methodology and tools to assess bioenergy systems, including their economics, energy balance, carbon flows, and leakage effects.
	Stakeholders and capacities
	Key stakeholders in national bioenergy efforts;
	Information generation and flow among these varying sectors;
	Capacities related to each stakeholder to help promote information flow, capacity building, and courses and curricula.
Economics of production and consumption	
Type of bioenergy and technology;	
Costs across the supply chain:raw material production orgathering, processing, transport, and infrastructure modifications (if any)	
Value of by-products;	
Local costs of alternative energy sources;	
Opportunity costs of land, labour and water used;	
Monetizing environmental externalities.	

POLICY	While these areas of policy development are highly relevant, their interaction and integration is even more important. Bioenergy can give rise to important trade-offs between different policy goals.	
	Agriculture and Food Security	<ul style="list-style-type: none"> Risks to food security of various bioenergy scenarios and possible ways to avert them; Positive impacts of expanded bioenergy due to diversification, new rural infrastructure, and jobs; Potential benefits or harm to affected populations; Present and future prices, markets, and subsidies; Potential export markets for possible surpluses; Impacts of second-generation systems on the structure of agriculture; International cooperation opportunities in bioenergy production and trade.
	Energy	<ul style="list-style-type: none"> Bioenergy's viability as an energy option and its present role in the national energy balance; Future role of bioenergy under various scenarios; Technological options in those scenarios; Knowledge and expertise available in the country. Bioenergy's role in energy-efficiency policies; Costs and prices of biomass-based energy carriers; Current taxation and subsidy situation in light of future bioenergy scenarios.
	Support to Bioenergy (incl. Fiscal)	<ul style="list-style-type: none"> Economic and social costs and benefits of different types of support: subsidies, import tariffs and other import restrictions, and consumption mandates; Magnitude and types of subsidies: tax reduction, tax credits, loan guarantees, subsidized credits, income tax reduction, tax holidays, and cash subsidies linked to production levels; Net loss in government revenue and what other government programmes will be cut as a result, where additional taxes may be levied to offset the loss in revenue, and alternative uses of government subsidies; Impact of a consumption mandate on domestic fuel prices in times of supply shortage due to weather- or pest-related crop failures; Economic and social benefits of increased bioenergy production and/or consumption as a result of government support.
	Rural development	<ul style="list-style-type: none"> Integration of bioenergy development into existing rural development policies and programmes; Number of jobs to be created under the various bioenergy scenarios; Quality, safety, and health characteristics of these new jobs; Impact on rural development (determined by establishing baselines and indicators); Incorporation of these indicators into wider efforts to assess sustainability of bioenergy activities; Monitoring and assessment of new investments due to bioenergy expansion.
	Land use	<ul style="list-style-type: none"> Protecting small-scale farmers from loss of land due to pressure from large-scale producers; Respect for and protection of land tenure rights; Use of "informed decision-making" and full participation of stakeholders when determining land-use changes; Assessing existing land-use policies in light of potential expanded bioenergy use.
	Environment	<ul style="list-style-type: none"> Impact assessments; Emissions monitoring and reduction; Biodiversity protection; Water use management; Soil health maintenance.
	Industry	<ul style="list-style-type: none"> Agro-industry, which will gain in importance as it transitions to providing energy in addition to food and feed; Forestry industry, which will gain new markets, new value creation opportunities for its wastes and low-value timber, and enhanced scrutiny as forests are more intensively managed; Energy industry, including established electricity and fuel providers who are central to energy distribution, as well as large-scale investors in new energy and fuel generation capacity; Small- and medium-sized enterprises, which will be critical to the achievement of development goals associated with bioenergy provision.
	Research and Development	<ul style="list-style-type: none"> Identifying bioenergy needs in the specific country context; Identifying where the R&D community in the country has comparative advantage; Ranking priorities so as to bring online as rapidly as possible those technology options with the greatest environmental and social benefits, as well as the best chances of becoming commercially competitive; Identifying policy needs and areas for policy research.

ACTION – SOME OPTIONS	Develop intersectoral plans and programmes on bioenergy	Identifying bioenergy options suitable for the country and ranking them in order of greatest environmental and social benefits and potential commercial competitiveness;
		Identifying R&D needs for both policy and technology innovations;
		Establishing normative and legislation frameworks;
		Formulating projects, which are critically important at this stage in the development of bioenergy. On-the-ground experience in a variety of contexts and the dissemination of lessons learnt are necessary to foster the sustainable growth of these industries;
		Developing intersectoral cooperation among all sectors involved and affected by bioenergy.
	Support R&D for bioenergy	Carrying out policy research for bioenergy, including appropriate forms of government support, identification of barriers to uptake, and policy response to the barriers;
		Identifying areas of unique interest in the developing-country context (e.g., use of straight plant oil in stationary engines in remote areas for electricity generation) and funding R&D, as appropriate;
		Facilitating collaboration among researchers nationally and internationally.
	Facilitate transfer of technologies and sharing of information (incl.)	Reducing border barriers to imports of technologies and materials needed;
		Tapping into modern technology information sources.
	Build capacity of and educate participating decision-makers (incl.)	Rural organization members and farmers/producers;
		Policy makers;
		Investors and financiers;
		The public and consumers;
		Academic and research communities;
Entrepreneurs; NGOs.		
Build capacity in the following areas:	Managerial skills;	
	Technical skills;	
	Trade-related issues;	
	Marketing and public outreach;	
	Negotiation and investment.	
Provide financial support (incl.)	Financial schemes at various levels, including for small-scale producers;	
	Utilizing micro-finance and other innovative mechanisms;	
	Providing public sector loan guarantees and other risk-mitigation mechanisms to enable more private investment in new technologies;	
	Enabling public-private partnerships.	

INTERNATIONAL LEVEL	
UN-Energy proposes the following steps towards sustainable bioenergy development at the global level:	
Identify, develop, and monitor the qualitative and quantitative implications of expanded bioenergy development for key sectors, including agriculture, industry, health, environment and trade;	
Promote international research on the social, scientific, technological, economic, policy, and environmental issues guiding bioenergy development;	
Encourage additional research and greater sharing of technology development by the concerned stakeholders, including private sector entities, and making greater use of existing international consultative arrangements, including the Consultative Group on International Agricultural Research;	
Promote the sound development and coordination of current information systems on bioenergy;	
Encourage the Parties to the Conventions on Biological Diversity and on Combating Desertification to consider opportunities for sustainable cultivation and utilization of energy crops;	
Establish internationally agreed standards and other certification models for production, conversion, use, and trade of bioenergy systems to protect both society and the environment;	
Develop sustainability criteria and analytical tools to be mainstreamed into projects and programmes;	
Establish methodologies under the Kyoto Protocol's Clean Development Mechanism for the assessment of bioenergy systems, including second-generation technologies;	
Promote international transfer of technologies, expertise, and experience in bioenergy between all countries, in both the industrialised and developing worlds.	

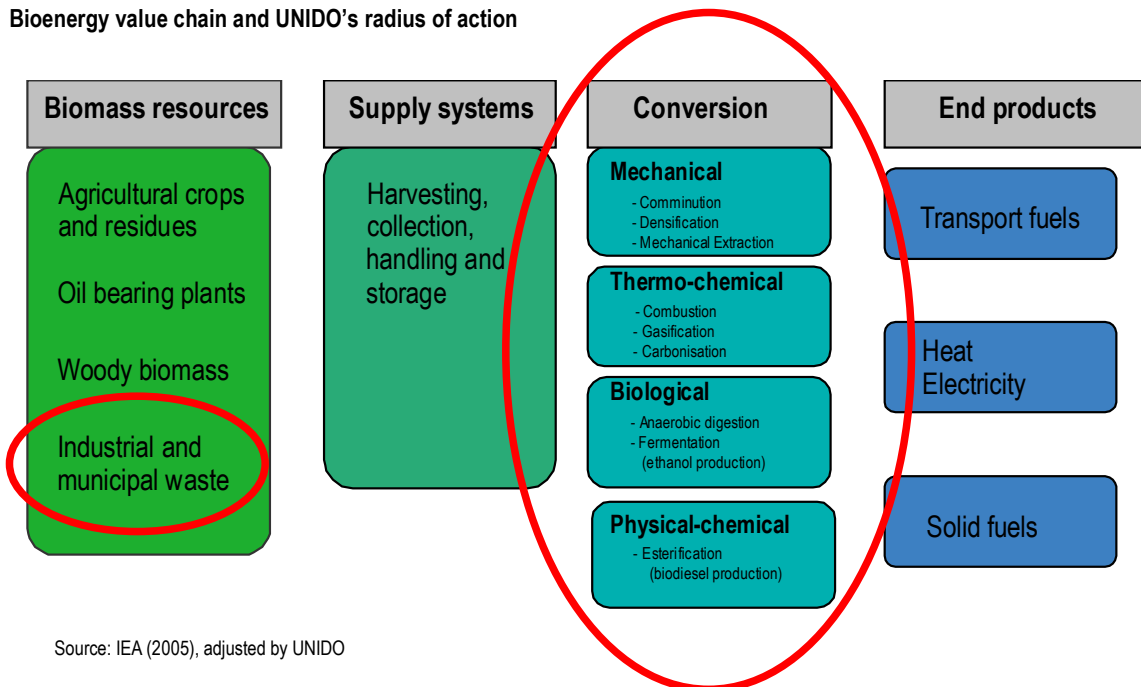
This comprehensive list of actions gives a clear indication as to where assistance is required. In the following sections an outline is given as to how UNIDO intends to address the issues relevant to its mandate.

c. [Existing support for developing countries in bioenergy: gaps that UNIDO can fill, customer demand](#)

Bioenergy are a rather new issue for nearly all institutions. Most other UN and multilateral organizations, national institutions, and the private sector are currently formulating their positions, approaches, and partnerships with respect to bioenergy. On the UN level, only FAO, UNEP and UNCTAD are clearly “visible”, while all others are currently considering their approaches, and strategies. Bioenergy are seen as a major option to reduce poverty (FAO 2006), to increase income in rural regions (UNCTAD 2005), and to contribute to greenhouse-gas reduction (UNDP 2005).

The role that industry plays in biomass flows, where it converts agricultural and forestry commodities into food/feed products, biomaterials, and bioenergy, can be best illustrated by the following figure:

Bioenergy value chain and UNIDO's radius of action



Source: IEA (2005), adjusted by UNIDO

Industry, and particularly SMEs occupy key functions in:

- Producing food, feed and fiber (food industry; pulp & paper industry etc.);
- Preprocessing wastes and residues (e.g., pelletization);
- Manufacturing equipment with various technologies (assembly / maintenance, logistics); and
- Converting feedstocks into bioenergy (combustion, fermentation, gasification etc.).

Timing for UNIDO's bioenergy initiative is good as intense endeavours are currently underway to form cross- and inter-agency cooperation with links to other multilateral organizations (G8, IEA, UNF, FAO, WB, UNDP and UNCTED), and create “hubs” to focus and disseminate relevant information such as the Global Bioenergy Partnership (GBEP) supported by the Government of Italy and hosted by FAO. At regional levels, EU (and most of its Member States), Japan, and the USA are committing significant R& D resources to bioenergy, as well as actively formulating and implementing policies for further bioenergy in their markets. The Energy Centre at the Swiss Federal Technical Institute in Lausanne (EPFL) is coordinating a multi-stakeholder effort, the Roundtable on Sustainable Bioenergy.

At global level, bioenergy trade and sustainability concerns are key issues under discussion and have called for international action to safeguard against negative social and environmental impacts. A variety of voluntary schemes

like product labeling and certification, but also suggestions for internationally binding regulation for governmental support schemes (e.g., subsidies or preferential treatment) are currently researched and discussed widely.

d. [UNIDO's capacity to fill gaps \(modified SWOT analysis\)](#)

UNIDO has a long and excellent record of promoting bioenergy technologies, especially regarding biomass gasification for electricity and process heat (with Indian Institute of Sciences in India and other partners). Furthermore, UNIDO has outreach to core industries in biomass area (agro, wood), and have started developing programmes on bioenergy. Biogas, sustainable forestry management, and related work on standards are already part of the cleaner and sustainable production and agro-produce waste management activities, which are an element of the UNIDO/UNEP network of National Cleaner Production Centers. UNIDO's work on the CDM has great relevance for bioenergy, but is so far more focused on the mechanism itself than on specific projects.

UNIDO carries out capacity building, technology assessments, information dissemination, training, and evaluation in areas close to bioenergy. Here, the International Centre for Science and High Technology (ICS) in Trieste is a special asset of UNIDO, which currently prepares a survey on available and emerging technologies for bioenergy production, especially for palm oil as a feedstock. In that context, an electronic decision-support tool is being developed. In cooperation with industrial partners such as the Malaysian Palm Oil Board, ICS works on catalytic processes for palm oil-based biodiesel, glycerol as a feedstock for fine biochemicals, and related issues.

UNIDO's internal strength lies in the integration of services related to bioenergy: Agro-Industries (Module 5), and Sustainable Energy and Climate Change (Module 6) are key, while Investment & Technology Promotion (Module 2), Industrial Competitiveness and Trade (Module 3) and Environmental Management (Module 8) present opportunities in the future.

With respect to bioenergy development in developing countries, UNIDO's strength is that the organization:

- Maintains very good links to relevant industrial sectors (especially SME) which are key future players in the Bioenergy / bioenergy arena, and its Service Module 2 (Investment & Technology Promotion) could be seen as an asset with respect to (needed) investments in the biomass conversion technologies market of developing countries;
- Maintains country-level implementation nodes, and regional offices, but it also has business-related networks, especially the Investment and Technology Promotion Offices (ITPO);
- Maintains own research capacities (e.g., ICS Trieste), and operates active collaboration with RTD partners in developing countries;¹⁰
- Addresses B2B issues and customer outreach problems related to bioenergy, through its joint effort with UNEP-DTIE in the CP area;
- Can rely on its SME partnerships and outreach/training activities, which are valuable routes to convey and disseminate information and data on bioenergy in general, and bioenergy in particular;
- Provides access to environmental support systems through its Cleaner Production Centers and can make use of those centers for information dissemination and training programmes on bioenergy;
- Works on export consortia which is a potential – but excellent - base for bioenergy considerations from a developing country point of view;
- Works in the area of Trade Capacity Building and has the largest portfolio among UN agencies – a clear “strategic asset”;
- Has activities regarding CDM, which could be extended to cover bioenergy, thus making use of its industrial outreach.

Concluding from the above list, UNIDO has excellent opportunities to move itself into the center, and to create valuable inputs for the bioenergy development at large.

On the other hand, it must be acknowledged that UNIDO has currently:

¹⁰ UNEP manages this through its network of collaborating centers.

- No immediate access to (bio) fuel distributors, and bioenergy logistics;
- No strong link to prime technical institutions for the biochemical route to bioenergy, as well as weak ties to bioenergy industry associations;
- No working relationship with the (base) chemical industry converting biomass.

3. The Bioenergy Programme

a. [Vision and Objectives, including statement explaining the role of bioenergy in the overall Renewable Energy Programme and Energy and Environment thematic priority](#)

Availability of energy is central for poverty reduction. UNIDO's energy programme aims to reduce and/or remove the obstacles that hinder the access to affordable and sustainable energy in poor rural areas of developing countries, in particular LDCs, and to demonstrate the economic and technical viability of modern energy systems based on locally available renewable sources (biomass, solar, wind, mini-hydro) while building the productive capacities needed to sustain those systems.

In this context of promoting renewable energy sources, bioenergy plays an important role in realizing UNIDO's mandate and addressing different Millennium Development Goals as

- bioenergy for electricity, heat and transport is a key option to ensure access to energy, especially for rural areas;
- bioenergy provides an opportunity to promote establishment of local small businesses, and thereby create economic revenue, and employment;
- bioenergy contributes to diversifying energy supply, and hedging risks of impacts from global fossil fuel price increases;
- bioenergy provides a means to reducing greenhouse gas emissions, especially by applying the CDM.

It is UNIDO's vision to be the lead UN agency to enhance access to energy, diversify fuel supply sources, create income opportunities in rural areas and reduce greenhouse gas emissions by promoting sustainable industrial conversion processes and productive uses of bioenergy.

UNIDO's programme objective is to ensure that its client government institutions, private sector and industry related organizations are in a position to take effective and efficient decisions on their bioenergy programmes, especially with respect to the selection of available technologies and the steps required to adopt promising technologies currently under development..

b. [Target clients and beneficiaries of UNIDO Support](#)

Clients are:

- Governments and national institutions dealing with policy and regulatory issues;
- Industry associations;
- Universities and research institutes;
- Banks and investment funds.

Target beneficiaries are:

- Small and medium sized enterprises, which manufacture equipment for the biomass conversion industry, preprocess (e.g. pelletise) or process biomass for food, feed or fuel production (food, pulp and paper, chemicals), or have access to energy (biodiesel for generators, biomass gasification for electricity grids).

- Small farmers benefit by having access to biodiesel to run their generators or their agricultural machinery. In addition, they may make additional income from preprocessing biomass as feedstock for bioenergy production.
- Larger private and public entities such as energy/electricity suppliers.

c. [Services to be provided](#)

1. Proposed UNIDO services

The main focal areas where UNIDO will contribute to the bioenergy field with own programmes and projects are as follows:

1. Bioenergy for industry
2. Bioenergy and its implications for Climate Change
3. Solid biomass for heat and power: South-South technology transfer and commercialization
4. Liquid biofuels: Ethanol from residues and wastes - demonstrating the value chain
5. Liquid biofuels: Biodiesel - building the local-global bridge for SMEs
6. Biogas from industrial wastes
7. Biorefineries: providing clearinghouse services

1. **Bioenergy for industry**

UNIDO will help create clear “profiles” of productive and sustainable bioenergy provision and uses, in particular highlighting that this comprises far more than biofuels for transport. Best practices will be made visible, including information on sustainable bioenergy potential, and employment and poverty reduction benefits.

Bioenergy need investments, i.e., an active role of the private sector. Financing of bioenergy projects will occur only if stable markets with adequate revenues are perceivable for investors, especially with regard to SMEs. The availability of data on and experiences with conversion technologies in terms of cost, efficiency, emissions, maintenance requirements, and suitability for developing countries is crucial.

As uncertainty on future potentials exist, integrated country analyses are needed to address different land-use priorities. Country case studies with industry partners are needed, and national workshops to disseminate results and define national bioenergy strategies.

Profiling and country assessments to determine potential business opportunities in the bioenergy sector need to be carried out with partners in developing countries already having capacities to implement bioenergy programmes (e.g., Argentina, Brazil, India, Malaysia, South Africa, etc.). At the same time, less advanced countries can benefit from South-South cooperation with those more experienced partners. Given that the use of modern bioenergy is relatively new, developing countries have few own capacities to research, consider, and evaluate such business opportunities. Hence, there is a clear need for integrated national strategies which take into account the specific settings of SMEs in the value chain.

Last but not least, UNIDO is in a unique position to contribute to the emerging issue of sustainability standards for bioenergy. UNIDO’s approach is to disseminate relevant information to its partners in industry, and to assist bioenergy industry associations and representatives from developing countries to actively participate in this area.

2. **Biofuels and the implications for Climate Change**

While renewable energy projects as a category are doing well in CDM, development and approval of biofuels projects is clearly stagnating. Of the nine submitted methodologies, only one has been approved, namely, production of biodiesel based on waste oils and/or waste fat from biogenic origin for use as fuel, and no projects using this methodology have yet been submitted to the Executive Board of UNFCCC.

UNIDO will assist in the identification and development of CDM projects in biofuels with a particular focus on Africa.

3. Solid Biomass for heat and power: South-South Technology Transfer & Commercialization

UNIDO will support the South-South technology transfer and market introduction of biomass gasification in partnerships with respective industrial developers in the (smaller-scale) power sector. Collaboration with IEA Bioenergy Task 36 could bring in a North-South component. The activity will build on the successful establishment of the UNIDO Center of Excellence for biomass gasification at the Indian Institute of Sciences in Bangalore, India. Few large-scale demonstration plants are already under implementation in several countries. In that regard, UNIDO will also highlight biomass cogeneration as a key option for CDM based on its own work in that area.

4. Liquid Biofuels: Ethanol from Residues and Wastes – demonstrating the value chain

UNIDO will focus in the near-term on the conversion of residues (especially from food industry) to ethanol. Guidance on and technology assessments of all bioenergy pathways will be made available to UNIDO's clients. For ethanol from industrial wastes, a pilot programme will be established in which participants from SMEs in developing countries, and donor contributions (e.g. from DFID, GTZ, KfW, as well as GEF) will be sought.

5. Liquid Biofuels: Biodiesel - Building the Local-Global Bridge for SMEs

UNIDO will foster decentralized biodiesel production, where issues such as feedstock availability and cost, fuel quality, labor safety, and environmental performance would be addressed. UNIDO aims to establish a (possibly virtual) "round table" on experiences with decentralized biodiesel production, and will create a platform for data, manufacturers, and successful projects. For this, UNIDO will strategically use and extend its current activities with ICS Trieste.

UNIDO will contribute to "bridge" rural bioenergy developments with respect to global trade and markets by establishing links between respective SMEs, its own trade activities, and logistic providers to bundle the potential of decentralized biodiesel. Malaysia's private sector initiative to demonstrate best practices in producing palm oil sustainably will be supported.

6. Biogas from Industrial Waste

Most agro-based SMEs generate significant amount of biowaste. This waste can be used to generate biogas, which could in turn be used to generate process heat or used to generate electricity. The production of energy from biowaste from SMEs presents several advantages to SMEs including enhanced productivity and competitiveness. UNIDO will contribute to the development of promotion of such technologies in relevant SMEs through technology transfer support, capacity building and investment promotion.

7. Biorefineries: Providing Clearinghouse Services

UNIDO aims to set up a clearinghouse service on biorefineries as a special contribution to the ongoing establishment of global knowledge hubs (or platforms) within the UN System. Here, UNIDO's technology assessment capacities, its existing channels for disseminating information, and its collaboration with industry and research partners in developing countries and the Cleaner Production Centers are key assets.

2. Service delivery

Inter-agency co-operation: In view of the multi-disciplinary nature of bioenergy UNIDO cannot and should not operate in isolation of its UN partners. Any programme needs to be coordinated closely with other agencies and partners (for instance, focus of FAO programme is on biomass feedstock supply issues). Therefore, UNIDO's plans to have a joint unit with FAO are key to the success of any bioenergy programme. UNIDO should assist in strengthening FAO's International Bioenergy Platform by serving as the SME information intermediary, i.e. a one-stop shop for bioenergy conversion issues.

Furthermore, UNIDO needs to more actively participate in currently on-going initiatives by the UN system such as GBEP and in system-wide programmes such as the development of a Bio-Wikipedia system. Other examples of co-

operation with UN partners are joint research programmes, particularly in the areas of profiling and preparation of country assessments.

In-house co-operation: As stated earlier in section 2.d., SWOT analysis, UNIDO's strength lies in the fact that it has several service modules, which lend themselves to supporting an inter-disciplinary bioenergy programme. The challenge is to make use of all tools, methodologies and existing centers for developing and promoting a focused bioenergy programme.

In developing countries, small and medium-sized enterprises (SME) play a central role in the conversion processes of bioenergy. Across the value chain different cross-cutting issues, which are of relevance to UNIDO's stakeholders such as policy makers, investors, entrepreneurs, industry associations and researchers, need to be addressed. Examples where in-house and inter-agency co-operations are beneficial include:

- Capacity building for policy makers to enable legislative and policy decisions in support of bioenergy production. This includes research on lessons learnt, what works what doesn't in which context, as well as organization of training programmes and development of training modules on bioenergy – activities, which can be performed by ECB/RRE in close co-operation with ECB/EE and PCF/RST as well as other UN agencies such as FAO and UNEP, and bilateral agencies active in this field (GTZ, SIDA, Dutch);
- Institutional support to SMEs to promote bioenergy production for local productive use to enhance rural development and create employment. This would involve support to local bioenergy industry associations to provide technology advice and business support services (through cluster programme or Cleaner Production Centers) – activities, which can be performed by ECB/RRE in close co-operation with ECB/CP, PSD, and AGR.
- Institutional support to SMEs to promote exports (through existing cluster programmes or Cleaner Production Centers). This may include investors fora and assistance in the implementation of sustainability standards – activities, which can be performed by ECB/RRE in close co-operation with ITP and TCB as well as UNCTAD and bilateral agencies.
- Demonstration projects to directly support SMEs in production of bioenergy and manufacturing of equipment for energy producers. This involves technology transfer activities such as technology selection, acquisition and adaptation and analysis of local market conditions – activities, which could be performed by ECB/RRE in close co-operation with PSD.