Biofuels Assessment on Technical Opportunities and Research Needs for Latin America

Executive summary:

Due to the high potential of biofuels in Latin America (LA) and the increased demand for biofuels in Europe (EU), the aim of the European Commission was to identify scientific and technological cooperation opportunities with Latin American stakeholders. Therefore, the European Commission supported the BIOTOP project 'Biofuels Assessment on Technical Opportunities and Research Needs for Latin America' (Contract No. FP7-213320) in the Seventh Framework Programme for Research and Technological Development (FP7).
This Publishable Summary Report of the BIOTOP project presents results of the project from 1 March 2008 to 31 August 2010. Various studies on the biofuel sector in LA were elaborated and provided a basis for the identification of research needs and cooperation opportunities. The BIOTOP consortium, consisting of five European and five Latin American partner institutions, identified these needs and opportunities in dedicated work packages on improved conversion technologies, standardisation and trade, as well as on sustainability. Scenarios on biofuels research were elaborated contributing to the development of policy and research recommendations. Finally, the project partners disseminated the project by different means, including the organisation of three EU-LA cooperation workshops in Sao Paulo (Brazil), Buenos Aires (Argentina), and Valparaiso (Chile). Furthermore, four study tours were organised: to the Biomass-to-Liquid (BtL) plant of CHOREN Industries in Germany, to a biodiesel plant in Argentina's main soy production area Santa Fe Province, to two biogas plants in Santiago de Chile, as well as to the lignocellulose bioethanol plant of ABENGOA and to the research facilities of CIEMAT in Spain. A final BIOTOP conference was organised in July 2010 in Brussels.

Project Context and Objectives:

The general objective of BIOTOP was to create and support Research and Technology Development (RTD) cooperation activities in the biofuels sector between Latin America and the European Union. The specific objectives were twofold: firstly, to foster the collaboration between European and Latin American stakeholders in the production of biofuels by identifying priority RTD needs and opportunities; and secondly, to increase awareness among European and Latin American stakeholders about technical opportunities and the large potential of biofuel production in LA. The BIOTOP project aimed to:
- provide a broad overview of the existing biofuel sectors in all Latin American countries,
- identify priorities, needs and opportunities in the field of RTD for sustainable biofuel production and biomass conversion technologies,
- inform European and Latin American actors in the biofuel sector about specific, mutually interesting areas for increased collaboration and partnerships,
- harmonise the research agenda between Latin America and the EU on sustainable biofuel production,
- facilitate and advance mutual knowledge and technology transfer between biofuel stakeholders in LA and the EU, and to make recommendations on RTD and policies for improved biofuel conversion technologies.

Main results of BIOTOP:

The BIOTOP work programme was divided into a set of different work packages (WP). The main results of BIOTOP were achieved in the following WPs:
- Mapping of existing biofuels sector in LA
- Improved conversion technologies
- Sustainability of biofuel production in LA
- Standardisation and trade
- Scenarios and roadmaps of biofuel RTD in LA
- Policy Recommendations on RTD in LA and EU-LA cooperation, and
- Stakeholder consultation and project dissemination

Conclusion
In summary, the main conclusions of the BIOTOP project are as follows:

- There is considerable potential for additional biofuel feedstock production in Latin America, also for export to the EU. However, more research on the real potential for biofuel production in Latin America including environmental and socio-economic aspects and limitations is urgently needed.
- The status of developments of biofuels in LA countries is very different. For instance, Brazil has large and long experience in ethanol from sugarcane due to supportive policies and efficient production. On the other hand, the potential for first generation biofuels in Chile is very small. Therefore, the government in Chile emphasised the development of second generation biofuels, mainly ethanol from lignocellulose.
- A large number of specific research topics could be addressed in joint EU-LA cooperation. The focus shall be on efficiency improvements of existing conversion technologies (first generation biofuels). Research on second generation biofuels is also very promising, especially if residues and co-products are used as feedstock. Thereby, research on biochemical conversion routes (e.g. ethanol from lignocellulose) in LA seems to be more advanced than research on thermo-chemical pathways (e.g. BtL).
- Sustainability of biofuels in LA is a key priority. In most countries, environmental and social legislation is in place in order to guarantee sustainability of biofuel production. However, in many cases, legislation is not enforced and thus contributing to the production of non sustainable biofuels. This is not only a problem for biofuel, but for many agricultural commodities. Therefore, the interaction between and the impacts of different uses of agricultural products have to be investigated. Tools to support sustainability of biofuels have to be developed and implemented. Sustainability schemes however shall not discriminate smallholders due to high costs or administrative burdens.
- Fuel quality standards are no major barrier for global biofuel trade since biofuels are adjusted to the specific needs of different countries. However, standards shall be harmonised in order to reduce costs and efforts. This is more relevant for biodiesel than for bioethanol which is generally more homogenous. Many LA countries are highly interested in export of biofuels, but increasingly also national markets are targeted by national biofuel policies.
- Mayor challenges and uncertainties for biofuel development in LA are agricultural intensification, water availability, and land management and availability for biofuel production. Future biofuel developments in LA are influenced by the demand for biofuels of emerging economies, such as China. Also the regulation or liberalisation of the global biofuel market as well as the success or failure of the global climate policy highly influences biofuel development.

Project Results:

Objectives of BIOTOP

Due to the high potential of biofuels in LA and the increased demand for biofuels in Europe, the overall objective of the BIOTOP project was to create and support specific RTD cooperation activities between Latin American and the European Union in order to maximize synergies in the biofuels sectors of Latin America and Europe. Specific objectives included:
- to provide a broad overview of the existing biofuel sectors in all Latin American countries. This also includes a broad overview of biofuel policies and strategies focusing on RTD in the field of second generation biofuels in both LA and the EU up to 2030;
- to identify priorities, needs and opportunities in the field of RTD for sustainable biofuel production and biomass conversion technologies at both national and regional level in Latin America;
Biomass conversion technologies at both national and regional level in Latin America;
- to inform European and Latin American actors in the biofuel sector about specific, mutually interesting areas for increased collaboration and partnerships;
- to harmonise the research agenda between Latin America and the EU on sustainable biofuel production and the integration of biofuels into the energy matrix;
- to facilitate and advance mutual knowledge and technology transfer between biofuel stakeholders in LA and the EU;
- to make recommendations on RTD and policies for the production and utilisation of biomass conversion technologies.

Mapping of existing biofuels sector in LA

An important task of BIOTOP was to map the current situation in Latin America regarding feedstock production, conversion technologies, biofuel markets, biofuel policies, research, and technical development. The objective was to provide a broad overview of the biofuels sector in all Latin American counties with focus on Argentina, Brazil, Chile, and Mexico. The results were published in various reports and on an interactive web-based 'resource and technology map of the biofuels sector in Latin America' presented at the BIOTOP website.

Feedstock production in LA

Feedstock production for biofuels is the first step in the biofuel value chain. Current and additional (potential) feedstock production in LA was assessed with special focus on Argentina, Brazil, Central-America, Chile, Colombia, Ecuador, Mexico and Peru. The analysed feedstocks were sugar crops (sugar cane, sugar beet, sweet sorghum), starch crops (corn, grain sorghum, wheat, cassava, potato, barley, oats, rice), oil crops (soy, peanut, castor, jatropha, rape seed, palm oil, sunflower), waste oils (animal fats), cellulosic materials (agro-industrial waste, short rotation woody crops, biomass from forest management, forest residues, not harvested forest growth), and wet waste (manure). The results are presented in the BIOTOP report on 'Feedstock Production in Latin America'.

The report concludes that there is considerable potential in Latin America for additional biofuel feedstock production. However, more profound research on the real potential for biofuel production in Latin America including environmental and socio-economic aspects and limitations is urgently needed. This could be done in a joint research effort between Europe and Latin America.

Existing biomass conversion technologies in LA

The BIOTOP report 'Overview of Existing Biomass Conversion Technologies in Latin America' aimed at assessing the current situation of biofuel production in LA. It provides data on current production of bioethanol and biodiesel in LA and describes the state of the art of existing production technologies and uses of co-products derived from production processes.

Bioethanol as transport fuel is mainly produced in Brazil, Colombia and Paraguay although at very different scale. Brazil is by far the Latin American leader in ethanol production accounting for 18 Million tons in the 2007/2008 harvesting season. In Central American countries as well as in Mexico and Bolivia ethanol production...
2007/2008 harvesting season. In Central American countries as well as in Mexico and Bolivia ethanol industry is at an early stage, with some initiatives to promote fuel-ethanol development in the short-to-mid term.

In all countries, ethanol is produced from sugar cane in a more or less integrated way with sugar production. The relative price of sugar and market demands determines the amount produced of each product. Various alternatives are used to obtain ethanol from sugarcane: direct fermentation of primary juice (mostly found in Brazil), of secondary or clarified syrups, of molasses, or even mixtures of them. The process to produce ethanol is a well-known technology comprising basically the steps of extraction and treatment of juice, microbial fermentation of sugars, distillation and optionally, dehydration. The use of main co-products from ethanol industry, i.e. sugar cane bagasse and vinasse, in power generation and crop ferti-irrigation, respectively, is a key factor regarding the economy and sustainability of the production process.

Biodiesel is principally produced from soybean oil in Argentina and Brazil, as well as from palm oil in Colombia. Biodiesel is produced by mature technology based on trans-esterification process in plants that are linked to vegetable oil extraction industries. The use of glycerine, the main co-product of the biodiesel industry, for application in food, drug and cosmetic industries depends on the market size of these applications and the economic feasibility to produce purified glycerine. Other alternatives for the use of crude glycerine (i.e. for heat production, as animal feed or as feedstock to manufacture high added value products) have to be considered.

Finally, the study emphasises the need to further improve the existing production technologies and to efficiently use the main co-products in order to increase the sustainability of the processes. The strength of cooperation efforts between Europe and Latin America in research and development in key aspects of the technology can greatly contribute to achieving this goal.

Biofuel markets and policies in LA

The BIOTOP report 'Overview of biofuel markets and biofuel applications in Latin America' describes the historic development of the biofuels market in LA and provides an overview of national biofuel markets, production capacities and trade streams in LA countries.

Special attention is given to the Brazilian bioethanol programme PROALCOOL, which started in 1975 and created the most advanced biofuel market in Latin America. Different stages and main drivers of the programme are described. During the late eighties, other Latin American countries attempted to develop domestic markets for ethanol, by means of regulations stating mandatory goals for ethanol admixture in gasoline. However, no country backed this policy with a comprehensive set of fiscal and financial supportive measures. For example, the Argentine programme for 'gasohol', started in 1985, was discontinued after a few years. And Guatemala's law for the promotion of bioethanol was passed in 1985 but did not achieve tangible results.

With the turn of the century, a new wave of laws and other policy instruments sprouted all over Latin America. Since 2001 laws and decrees for the promotion of biofuels were passed in Colombia, Peru, Costa Rica, Ecuador, Brazil, Bolivia, Paraguay, Argentina, Honduras and Mexico. The main drivers were...
Costa Rica, Ecuador, Brazil, Bolivia, Paraguay, Argentina, Honduras and Mexico. The main drivers were again the rising price of crude oil and concerns about the security of its supply. New, additional motivations also appeared, such as expanding international markets for biofuels, expectations to gain from global carbon markets, and opportunities to develop new agri-based industries.

Current legislation and policies in Latin America were mapped in order to assess their roles in biofuels development. The results are presented in the BIOTOP report 'Biofuel policies and legislation in Latin America'.

The document concludes that biofuels are discussed at different levels and even sometimes controversially depending on the government within Latin America. The main biofuel promoters are Brazil, Argentina and Colombia, whereas Bolivia, Venezuela and Cuba are currently sceptical towards biofuels.

Interactive web-based resource and technology map

In order to disseminate the data and results of the assessed data in LA, an interactive web-based resource and technology map was elaborated. This resource map is an integral part of the BIOTOP website and gives country specific information about the following issues:

- current biofuel markets
- biofuel policies
- feedstock production and potential
- biomass conversion technologies

improved conversion technologies

A core activity of the BIOTOP project was an assessment of improved conversion technologies and its applicability in LA. The objective was to identify research needs and technological opportunities for improved conversion technologies (first and second generation biofuels). This included technologies for ethanol from sugar cane and from cellulosic feedstock, biodiesel and pure plant oil (PPO), BtL (Biomass-to-Liquid) fuels, biomethane and full-scale integrated biorefineries. The assessment took into consideration state-of-the-art technologies and ongoing technological research from Europe and promoted EU-LA cooperation and knowledge transfer. The objective was to identify promising and improved conversion technologies suitable for Latin America. Therefore, the applicability of improved conversion technologies for selected sites in Argentina, Brazil, Chile, and Mexico was investigated.

Improved ethanol production technologies

The technological opportunities and research needs to improve fuel-ethanol production technology in LA were assessed. The results are described in the BIOTOP report on 'Improved Bioethanol Production Technologies'. Advances in current production processes as well as in second generation bioethanol production by the biochemical route were considered.

The study concludes that it is essential for Latin American countries to implement tools that allow to progress in the research, development and demonstration of improved and new feedstocks for ethanol.
progress in the research, development and demonstration of improved and new feedstocks for ethanol production as well as advanced transformation processes. It can be achieved taking advantage of the abilities of existing research teams, coordinating activities at national and international level and promoting international collaboration. To facilitate collaboration between private and public sectors involved in ethanol production and use and support investments in the sector aimed to improve both feedstock production and technology development, are identified as key factors to advance a well implemented ethanol industry in LA.

Improved biodiesel and PPO production technologies

The production of pure plant oil (PPO) as well as biodiesel even in large (industrial) scale is well established world-wide. The BIOTOP report on 'Improved Biodiesel and Pure Plant Oil Production Technologies: Technical Opportunities and Research Needs' showed that new 'improved' methods which are developed to offer higher conversion rates and better product and by-product quality are mostly at the experimental stage.

Investigations on production costs, which are initially higher for improved technologies, as well as sustainability criteria and LCA assessments, are still missing. Therefore the evaluation of improved methods is also covering detailed analysis of possibilities and needs when converting oil crops/fruits/seeds into PPO and biodiesel, respectively.

The potential for improvement is mainly influenced by the type of feedstock available. Classical oil crops for biodiesel production like soybean, palm, and rapeseed are well investigated and the production route from well-to-wheel is basically optimised. The situation is different for new or alternative feedstocks. Almost all steps from cultivation, harvesting, pre-treatment, pressing, purification, and further conversion e.g. into biodiesel have potential to be improved or optimised. Improved technologies or techniques exist but have to be correctly selected and implemented. In case of PPO, especially when obtained from new feedstocks, the pre-treatment of the harvested material is often the most crucial step. Improvements on handling, digestion, transport and logistics are the most challenging factors. Several oil fruits have to be processed quickly after harvesting to avoid deterioration, which influences the final quality. Also the selection of expelling routes (pressing or extraction) depends on the feedstock and its composition. Finally, the purification (refining) steps have to be adapted to the crude oil composition. Minimum requirements to fulfil PPO fuel specifications are degumming and neutralisation. But also physical refining and bleaching is sometimes necessary to guarantee oil qualities suitable for direct use or further processing into biodiesel.

Concerning biodiesel production several LA countries (e.g. Argentina) have significantly increased annual production capacities. Besides soybean and palm oil also other feedstocks (animal fats, castor) are being processed. Numerous small to large-scale production plants have been successfully installed in the last years using traditional biodiesel production technologies. Improvement of conversion (technology) is mainly necessary if plant operators aim at switching to multi-feedstock processing capability and/or by-product purification. The technology for such purposes exists and is usually easy to implement. Options for such retrofitting are e.g. installation of pre-esterification for high free fatty acid containing feedstocks (waste fats and oils), changing from batch to continuous processing to increase conversion capacity, installation of distillation facilities to further purify the biodiesel or the glycerol to pharmaceutical grade. The conversion (trans-esterification) process can be influenced (improved) by optimisation of catalyst type.
Conversion (trans-esterification) process can be influenced (improved) by optimisation of catalyst type and quantity, temperature, dwell time and alcohol-to-oil rate. Several new catalysts and reaction conditions with sometimes significant improvements on conversion rate and velocity are under investigation, but they are not fully implemented yet for large-scale application.

Research needs and EU-LA co-operation opportunities on PPO and biodiesel mainly focus on new feedstocks and sustainability assessments. Due to the increasing demand of oils and fats for biofuel production, fluctuating prices on the world market and controversial opinions on food versus fuel, the need for sustainable alternative feedstocks is the most important issue. Especially in this field several research is needed. The large number of plant varieties in LA connected with long term traditional experience on use and cultivation e.g. by natives, the number of LA research institutions working in this field, governmental interests and support, and the expertise of European research institutions, standardisation bodies and technology providers constitute an excellent platform for co-operation. Existing cooperations as well as those initiated through the BIOTOP project can be used for further intensification of knowledge and experience transfer. However, two crucial factors are precondition: institutional/financial support and the creation of a win-win situation for the involved countries avoiding ‘green colonialism’.

BtL production technologies

The report on ‘Biomass-to-Liquid Production in Latin America: Technical Opportunities and Research Needs’ shows that currently in Europe, research and technical development on BtL is increasing and considerable knowledge has been accumulated. Some steps of the process chain, such as the synthesis (e.g. Fischer Tropsch synthesis), are already mature and have been broadly implemented. For instance natural gas and coal can be used for gas synthesis within Gas-to-Liquid and Coal-to-Liquid processes, which can be applied to the Biomass-to-Liquid process. On the other hand, much progress is still needed for biomass handling and pre-treatment as well as for the pyrolysis, gasification and gas cleaning processes. Due to technical challenges in these process steps, the high investment costs for BtL facilities, and the high production costs of BtL fuels currently no BtL fuels are produced on commercial scale. Some examples of pilot plants based on different technologies are presented in this report. However, it is expected that the large-scale implementation of BtL technology will need at least ten more years.

In Latin America, only very little research on BtL is implemented and research, pilot and commercial BtL plants are missing. Very few stakeholders are already involved in BtL research, but many stakeholders are interested in this new technology. This could be a good starting point for international cooperation between Europe and Latin America. Latin America has two main drivers for BtL exploitation: (1) Latin America is endowed with natural resources (wood, energy crops, waste such as bagasse) and could be an important feedstock provider and (2) some Latin American countries, such as Brazil, have successfully implemented large biofuel programmes since many years (e.g. PROALCOOL), facilitating the broad introduction of new fuels.

Cooperation between Europe and Latin America may be established through common research projects as well as through public-private partnerships. In a joint cooperation programme, Europe’s role could be to build capacity among researchers and engineers, transfer knowledge about the BtL conversion process gained from research in Europe and experiences from the pilot and demonstration plants, and to facilitate the set up of pilot plants through its expertise and experience.
Latin America's role could be to install research facilities in Latin America, to increase capacity among Latin American researchers and to provide local expertise on Latin American framework conditions, especially on feedstock production. New Latin American feedstock types, suitable for BtL production, have to be identified, logistic requirements investigated, and pre-treatment technologies adapted.

Apart from joint cooperation efforts, there is generally a large need for further research on the whole BtL process chain and for large investments to set-up more pilot, demonstration, and commercial plants.

Full-scale integrated biorefineries

The BIOTOP report on 'Full-scale Integrated Biorefineries' assessed the feasibility of implementing advanced biorefinery concepts in LA identified main barriers and formulated policy outlines and recommendations for RTD.

The development of biorefineries in LA has so far focused on first generation feedstocks. However, sustainability and strategic issues indicate the convenience of assessing the potential for the development of advanced integrated biorefineries concepts based on alternative feedstocks. The use of biomass carbohydrates for non-food uses currently plays a very modest role for the production of basic chemicals and commodities in LA. This is because hydrocarbon products are generally cheaper and require lower investments. Currently, most biorefinery concepts in LA are developed close to agro-industrial activities, have an incipient level of integration of processes and produce a very limited range of non-feed/food products.

Applied research is quite advanced on specific components of alternative biorefinery concepts, with higher geographical coverage in Brazil, Argentina, Chile, Cuba and Colombia. Cooperation with the EU already exists in this area. However, research on integration of processes is much weaker, with some examples in Brazil and Argentina. Furthermore, there is a gap between research projects and demonstration and pilot projects, mainly due to the lack of funds available for those activities. The alternative feedstocks bagasse, micro-algae, effluents and agro-industrial residues receive attention in some countries of LA, though these efforts seem to lack coordination and are generally limited to laboratory stages. Polymers and other high value co-products are being produced in laboratory and pilot stage in the region.

Under the current unclear framework circumstances the most adequate approach to biorefineries development in LA is to focus on the coordination and financial support of existing RTD activities in the most promising alternative biomass feedstocks, processes and integration opportunities as identified in the report. It is recommended that cooperation agencies, industries and governments support research, streamlining and integration of processes that are currently under basic and applied research.

Selected alternatives should avoid the main negative impacts associated with first generation feedstocks and practices. In general terms, it is recommended that Latin America biofuels development trends be based on sound policy and information concerning the potential impacts on the society as a whole.

Improved biomethane production technologies
The report 'Production of biomethane and its use for transport applications' describes the production of biomethane (upgraded biogas) and the use for transport applications. It focuses mainly on using biomethane for road transport, since this is currently the most widely applied technology. To reflect the close linkage with the use of natural gas (NG), both the application of biomethane in NG vehicles and the injection of biomethane in the NG grid are covered.

An additional report on 'State of the art in biogas - Short country profiles for Argentina, Brazil, Chile and Mexico' contains short country profiles briefly discussing the status of biogas production, the current use of natural gas and the potential for biomethane in transport applications in Argentina, Brazil, Chile and Mexico.

In conclusion, biomethane production and use around the world has thus far been limited to a few selected European countries. Raw biogas is produced in many developed and developing countries, sometimes even in substantial quantities, but practical experience outside the Western world with upgrading of the biogas to biomethane quality and subsequent use as transport fuel is very limited. One exception has been a project of the Indian Institute of Technology in which biogas was upgraded to biomethane that was bottled for use in vehicles.

Major bottlenecks to the larger uptake of biomethane are its relatively high costs (electricity and natural gas are subsidised), the relatively large scale of operation required, the complexity of projects, and the need for a natural gas grid infrastructure. In Latin America a number of biogas plants have been constructed. However, the total number of plants remains rather modest. The four Latin American countries (Argentina, Brazil, Chile and Mexico) report between 15 and 45 biogas plants each, either in operation or planned. Few of the identified plants produce electricity, let alone upgraded biogas (biomethane).

Although no detailed assessment was made of the barriers to the wider application of biogas for advanced applications (grid-connected power generation, feed-in into the natural gas grid, transport sector), it would appear that unfamiliarity with the upgrading technology, legal restrictions and poor economics in the Latin American setting are important barriers. An exception is the biogas plant at la Farfana (Chile), where sufficient biogas is produced and later upgraded to substitute 11-12% of the natural gas in the gas grid feeding (parts of) Santiago. This would seem to be the only location in the investigated Latin American countries where biogas is upgraded to natural gas quality.

The identified barriers help explain the total absence of biomethane-fuelled vehicles in Argentina and Brazil, which host the second and third largest compressed natural gas (CNG) fleets in the world (1,750,000 and 1,600,000 vehicles respectively).

It can be assumed that in Latin America barriers against further development of the biogas/biomethane market will not be addressed at any significant scale in the near future. Therefore, despite the general high potential, in the short-to-medium term (next five years) biomethane is unlikely to be used in the transport sector in LA. Instead, any growth in the use of biogas in Latin America is likely to concentrate on direct use as renewable fuel in industrial boilers or for decentralised electric power production and use. To support
as renewable fuel in industrial boilers or for decentralised electric power production and use. To support biogas/biomethane development in Latin America, research should focus less on potential application in the transport sector but more on traditional biogas applications and on widening the biogas feedstock base.

**EU-LA RTD cooperation opportunities and RTD needs of biofuel conversion technologies in LA**

As a main result of BIOTOP, the report on ‘Research Needs for Biofuel Conversion Technologies and Cooperation Opportunities between Europe and Latin America’ describes the research needs for different biofuel conversion technologies in Latin America and in selected Latin American countries (Argentina, Brazil, Chile, and Mexico). It furthermore, shows co-operation opportunities on biofuel conversion technologies between Europe and Latin America, including descriptions of existing co-operation, potential stakeholders, and potential tools for future research co-operation. Selected future research activities are proposed in order to facilitate streamlining the strategic research agenda of the European Commission.

The assessment of research needs on improved conversion technologies for biofuel production showed that the evaluation of research priorities on technological aspects shall always include non-technical aspects. In fact, several other issues in the context of biofuel production have to be mentioned and taken into account, leading to a more efficient overall production. This includes, for instance, sustainability aspects, economic issues, and feedstock potential. Furthermore, local conditions and requirements have to be considered in order to guarantee highest efficiency as well as highest added value for the involved persons (or regions). In this context, the conclusion reflects specific research needs for each biofuel chain but also overall needs in the whole production chain valid for all biofuels.

**First and second generation ethanol**

Ethanol is produced worldwide in large quantities and appropriate technologies for first generation ethanol exist. Research needs can be identified on adjustments of current technology as well as on alternative feedstocks. Second generation ethanol production is emerging but still in experimental scale.

Feedstocks are one of the most crucial factors of biofuel production. Feedstock quality, yields, and cultivation measures strongly impact conversion (technology). In terms of first generation ethanol production, additional research demand on improved crop resistance against pests and diseases as well as biomass production yield is identified. To meet future demand, new feedstocks like cassava, sweet sorghum, maize, etc. will need to be developed and their cultivation, harvesting strategies as well as logistics researched. On feedstocks for second generation ethanol production, the use of sugar cane bagasse, straw but also woody biomass has to be further investigated. The potential and use of suitable waste material for ethanol production has to be further assessed. Specific research demand is also identifiable on appropriate biomass pre-treatment to guarantee efficient conversion.

Specific emphasis should be put on improvements of the enzymatic hydrolysis step of the feedstocks as well as the fermentation technology itself with special focus on C5 sugar fermentation. The goal should be faster and more efficient production with higher yields and lower costs. A further point is the development of appropriate concepts and technologies to implement by-product or co-product utilisation (e.g. cogeneration) or conversion into higher added-value products (biorefinery concepts) to reduce wastes and
cogeneration) or conversion into higher added value products (biorefinery concepts) to reduce wastes and improve profitability. Specific additional research needs for second generation ethanol production are identifiable on the improvement of the whole production process from feedstock pre-treatment to fermentation and by-product purification and utilisation. In this context especially the evaluation of concepts for alternative feedstock processing linked with installation of small scale and demonstration units has to be extra highlighted.

Biodiesel and pure plant oil

A similar situation applies to research on biodiesel and pure plant oil. Appropriate technologies are available and large-scale production is state of the art. Research needs are allocated in terms of adjustments of existing conversion technologies, feedstock and feedstock pre-treatment but also on by-product processing and use.

For biodiesel the importance of alternative feedstock is even higher than for ethanol. However, concerns exist with respect to food-feed-fuel competition, indirect land use change and sustainability criteria (and limitations). Therefore, it is necessary to identify new, alternative, and efficient crops for fuel production. Research in this field has to be accomplished from well to wheel which includes cultivation, harvesting, transport, pre-treatment, by-product utilisation, pressing and refining, as well as conversion behaviour, distribution, implementation and sustainability. Especially LA countries with their broad feedstock variety are an excellent basis for further joint research activities. Decentralised concepts for feedstock production, conversion and use are promising options to evaluate potential crops. However, it should be pointed out that PPO as fuel substitute will cover only niche markets in medium term.

Important research fields on the conversion process of biodiesel production are mainly related to adjustments of existing technologies. Improvements on catalyst types and efficiency, washing and purification of the product as well as by-product upgrading are important. On the other hand conversion of fats and oils into fatty acid ethyl esters is of increasing interest and lack of knowledge and experience is still apparent. This field represents an excellent possibility to further cooperate on research including the installation and operation of demonstration or research plants. Coupled with alternative feedstock processing also the use of biodiesel and PPO has to be investigated by performing engine and road tests.

Biomass-to-liquids (BtL) fuels

BtL technologies are available, but large research efforts are still needed on feedstock pre-treatment and product purification to reach commercial levels. Today, there is a lack of demonstration plants, and research interests of LA researchers are very limited. BtL is suffering from euphoric expectations and promises which could not get fulfilled so far. Ambitious research demand is still needed on the potential and composition of appropriate biomass, development of pre-treatment strategies (drying, milling, grinding) which can also be part of decentralised concepts. Furthermore, waste material suitability and utilisation has to be assessed in order to develop multi-feedstock processing routes. Additionally, handling, storage and logistics of biomass for BtL purposes has to be further evaluated.
Biomethane and biogas

Biomethane as transport fuel application is currently of almost no interest within LA and therefore research in this field is currently very limited. On the other hand, some biogas installations for heat and power production are implemented in LA.

There is a research demand on suitable feedstock types, such as energy crops and waste materials. In this context also feedstock composition and co-feeding of by-products (e.g. glycerol from biodiesel production) has to be further assessed.

Demand is identified for further research on fermentation microbiology. Another point of interest is to improve the process in terms of conversion velocity, yields, specific gas composition, energy balance, and by-product utilisation. Especially digester automation and improved gas purification (and compression if biomethane is used as transport fuel) have to be investigated. If biomethane should be used as fuel it is necessary to develop cost-efficient biomethane upgrading technologies and to install appropriate demonstration plants.

Biorefineries

Several representative (different) biorefinery concepts have been introduced in LA. However, still lots of further research and improvements are necessary. Demand is identifiable on almost all different biorefinery concepts and implementation plans but specifically on feedstock pre-treatment and conversion as well as on product separation and purification.

The evaluation of appropriate feedstocks and the conversion potential of waste and by-products e.g. from biofuel industry is a high research priority. Especially research in algae as feedstock for bioproducts and biofuels as co-products is very important. Also the potential of wet biomass in general has to be further evaluated. Concerning solid biomass especially fast growing low lignin containing plants have to be investigated.

Manifold needs have been detected on the biochemical conversion of biomass due to the very complex conversion processes. There is large research needs on suitable enzymes and microorganisms in order to convert multilayer biomass into high value added products. Especially the pre-treatment of lignocellulosic and/or wet material is still a bottleneck of several biorefinery concepts. Another aspect which needs further investigation is the product separation and purification.

General research needs for biofuels

Apart from technological research needs, also economic, environmental and social research needs have to be specifically addressed in future European and Latin American research agendas.

As each type of biofuel requires specific feedstocks for its production, the impact of alternative feedstocks on total production costs has to be evaluated. In this context also the installation of appropriate waste feedstock collection systems has to be further assessed in terms of economical impacts. Another aspect is
feedstock collection systems has to be further assessed in terms of economical impacts. Another aspect is the evaluation of cost efficient production linked with optimisation (adjustment) concepts concerning energy efficiency, co-generation, and by-product conversion (or utilisation). Finally, comparative assessments are needed large (industrial) scale versus small (decentralised) scale production.

Public and scientific discussions address several environmental concerns with respect to feedstock, location, and conversion processes. In order to guarantee sustainable production, it is necessary to further evaluate feedstocks (especially future alternatives) in the context of GHG savings, LCA, ILUC, and biodiversity. Linked with the economic evaluation also the impact of the plant size on environmental issues has to be investigated. An important research field is the investigation of water and wastewater management of biofuel production in existing and new conversion chains.

In relation to the idea of implementing biofuel production in rural areas, the regional valorisation potential under local conditions has to be investigated. Employment creation potential and labour conditions of current and future biofuel production schemes must be evaluated. Additionally research has to be put on food security, land use and feedstock competition to guarantee sustainable biofuel production.

Sustainability of biofuel production in LA

An important aspect for current biofuel developments is the sustainability of the whole biofuel value chain. In order to evaluate the sustainability of biofuels, sound data on environmental and socio-economic impacts are needed. Thus, research needs on sustainability assessment were identified, and sustainability assessment tools were identified, described and compared to each other. Their applicability for various production systems was assessed.

Sustainability assessment tools for biomass production

Operable sustainability tools in Europe and Latin America were assessed and included in the two BIOTOP reports 'Initiatives and recent developments in EU Member States and at EU level towards the implementation of sustainability criteria for biofuels: Netherlands, United Kingdom, Germany, Sweden & European Union' and 'Overview of sustainability assessment tools for biomass production in Latin America'.

Application of Sustainability Tools for Biofuels in Latin America

The BIOTOP report on 'Application of Sustainability Tools for Biofuels in Latin America' includes a comparison of the national laws in LA with the RSB and RED sustainability schemes. It furthermore provides guidelines on actions needed to achieve compliance with sustainability schemes.

Even though only few countries have specific legislation addressing biofuels production, in most LA countries general national legislation on environmental and social aspects already exist and are sufficient to regulate sustainable production of biofuels. Comparing existing legislation with proposed certification criteria, there is a lack of legislation for establishing figures for GHG emissions in all Latin American countries.
Furthermore, there are several certification criteria mainly from industrialised countries and there is a need to develop a unique methodology for certification. The parameters adopted should be transparent and based on reliable and traceable data. It is important to develop a feasible methodology for monitoring and checking compliance. It is necessary that criteria and indicators are reflected in the regulations (of social and also environmental laws), as well as in sector programmes related to the sustainability of agricultural production in general.

In the case of GHG emissions, the calculation should be based on local studies, especially the emissions from indirect land use change (ILUC).

The costs related to the adoption of certification schemes should not jeopardize biofuels producers. Most importantly, this should not pose a high economic burden on small producers. It would be necessary to develop separate criteria for large-scale and small-scale feedstock and biofuels producers, in order to guarantee sustainable biofuels production.

It is also important to establish, in a first stage, minimum requirements that could allow developing countries in Latin America, Africa and Asia, to start producing biofuels and introduce more sophisticated rules at a later stage.

It will be very difficult for many Latin American countries, in which biofuels production or renewable energy use are still not well consolidated, to fulfil in due time all of the sustainability criteria that are indicated in the RED. Some mechanisms should be designed to help these countries comply with international standards as fast as possible.

Framework factors influencing sustainability criteria

The determination of sustainability criteria for the production of biofuels is affected by a number of factors, such as, economic and market factors, environmental policies, and socio cultural factors. The report on ‘Framework Factors Affecting the Determination of Sustainability Criteria’ investigates how these factors may affect sustainability criteria for biofuel production.

Economic and market factors are linked to the degree to which second generation or advanced biofuel technologies become commercialised, but also to the availability of agricultural land for both biofuel and food production. Unless advanced conversion technologies, which are less dependent on arable land, materialise, or/and yield productivity growth increases, pressure on increased food production will negatively affect the production of biofuels. Prices of feedstocks and fossil fuels, and the growth of demand in China, are other aspects linked to economic and market factors. Biofuel supply and demand is a function of their opportunity cost and the level of demand. Thus, the potential profit from producing food versus fuel will be crucial in this context. Similarly, continued domestic growth patterns in the Chinese market will have a significant impact on the growth of the biofuel market, and consequently on the sustainability of production in key regions such as Latin America.

The determination of sustainability criteria is affected by environmental policies, including the development of stronger climate change policies and renewable energy promotion policies. Examples of these are...
of stronger climate change policies and renewable energy promotion policies. Examples of these are sustainability schemes and protocols for biofuel production, as well as trade and mandates for the blending of biofuels into the gasoline or diesel pool. In a similar way, new political directions or research that shape the pace at which existing targets expand after 2010, and the degree to which compliance in member states is mandatory or voluntary will have a significant impact on biofuel production. To this, ongoing global efforts to limit GHG emissions have to be added. As one of the main suppliers to the European market, Latin American production will be directly affected by changes in EU fuel policies and global efforts to limit GHG emissions. In this context, the Clean Development Mechanism (CDM) under the Kyoto Protocol is another factor to be considered. Although this mechanism has not yet regulated or incorporated the production and consumption of biofuels, the possibility of doing that is not unlikely, which would have an impact on the determination of sustainability criteria of biofuels.

Another aspect embedded in the policy framework, is the evolution of sustainability and certification systems. Although a number of sustainability schemes have been developed, these have not been fully effective; either because they have met resistance from industry due to increased costs for compliance, or due to lack of monitoring. Nevertheless, increased efforts to put these systems in place in conjunction with more resources devoted to monitoring may result in increased demand for sustainability on biofuel production. Similarly, the potential inclusion of non GHG factors such as acidification, eutrophication and biodiversity loss, which is the result of use of fertilisers and have not yet been taken into account, also have an impact on the sustainability of biofuels.

Finally, although socio-cultural factors might sound less relevant in this context, they are likely to have a significant impact on the determination of sustainability criteria for biofuel production; public perceptions, and consumer preferences and attitudes being some of them. Consumer decision making and preferences are increasingly linked to public perceptions and status symbols linked to green behaviour, which particularly applies to Europe. The involvement of the public in the development and definition of sustainability criteria should therefore be taken into account. It is only then that issues like social equity and poverty impacts can be incorporated for the benefit of rural populations.

Standardisation and trade of biofuels

The main objective of the work carried out in the field of Standardisation & Trade was to identify research needs and technological opportunities for an increased and more robust trade between EU and LA in biofuel feedstock, biofuel production technologies and biofuels. The work was split into several tasks dealing on the one hand with standards and specifications for biofuels, and on the other hand with barriers and drivers relating to EU-LA biofuel trade.

Biofuel standards in LA and EU

The BIOTOP report ‘Biofuels Standardisation in the European Union and Latin America’ covers an assessment of the regulatory framework and procedures for developing biofuel standards, technical regulations, and conformity issues, both in the EU and in the participating BIOTOP countries in LA. The assessment includes standards on bioethanol, biodiesel, pure plant oil, biomethane and biomass-to-liquids (BtL) fuels. The report presents a comparison and evaluation of biofuel standards (bioethanol, biodiesel and pure plant oil) in LA and the EU.
The comparison of standards for bioethanol in EU, US and the BIOTOP countries shows that, despite many differences, there are only a few parameter limits that are considered unbridgeable. Particularly water content is a parameter that may be difficult to align. However, the differences cause no real obstacles to trade (e.g. the stricter level of maximum water content in the EN standard will require additional drying).

The comparison of standards for biodiesel in EU, US and the BIOTOP countries in LA shows that considerable differences exist. A significant number of parameters are regarded as 'difficult to align'.

Standardisation activities of BtL fuels are ongoing in Europe within the context of a CEN Workshop Agreement. However, no standardisation initiatives exist in Latin America or on global (ISO) level, although ASTM is developing a standard for synthetic diesel fuel oils.

RTD opportunities and needs of biofuel standardisation

The BIOTOP report 'Assessment of research opportunities and needs of biofuel standard development and harmonisation in Latin America' presents an assessment of research opportunities and needs of biofuel standardisation in Latin America.

Biofuel trade barriers and drivers

The BIOTOP report 'Assessment of barriers to the trade of biofuel between the European Union and Latin America' contains an assessment of barriers to the trade of biofuel between the European Union and Latin America. It summarises the current status of global biofuels (bioethanol and biodiesel) production, consumption and trade. It describes the regulatory framework for global trade, the rules on biofuels in WTO agreements, and the consistency of EU biofuel policy with WTO law. Next it introduces preferential trade agreements. Finally, international barriers and country-specific barriers to biofuel trade are discussed, and conclusions are drawn to what extent the various barriers impose limitations to biofuel trade between LA and EU.

Biofuel scenarios and roadmaps for LA

The findings of the previous chapters were used to develop biofuel scenarios and roadmaps in LA in order to serve as an inspiration source for the development of RTD and policy recommendations. Describing the potential for biofuels involves taking into consideration a series of uncertainties. This applies to LA as well as the rest of the world due to globalisation where developments in distant markets have significant impact on domestic markets, and might significantly change the required framework conditions for biofuel production. Therefore, the first step was the identification and analysis of uncertainties in order to predict their potential influence on future development of biofuels in LA. In a second step, different RTD scenarios were developed by using uncertainty factors. In a third step, RTD roadmaps were developed which help communicating RTD gaps in the biofuel production chain.
Uncertainties analysis

In order to identify uncertainty factors for biofuel development, a web-based questionnaire was circulated among more than 100 experts and stakeholders of whom more than 50% responded. The answers were run through a cluster analysis where large deviation in the answers of the same question indicate large disagreement and thus serve as indicators for uncertainty factors.

Scenario analysis

Based on the uncertainty factors, different future scenarios were formulated and finally three scenarios were described in the report 'Scenarios on future biofuel world markets, uncertainties and implications for Research and Technology Development in Latin America':

- Scenario 1: Biofuel blow-off in China
- Scenario 2: World crisis in economy and trade relations
- Scenario 3: Global biofuel joint-venture

For these scenarios, consequences (threats and opportunities) for biofuel exports from Latin America to Europe, for sustainability, and for RTD collaboration between Latin America and Europe were described.

BIOTOP Roadmaps

Finally, a RTD roadmap on biofuels in LA was elaborated illustrating short-, medium- and long-term developments and research gaps in order to support the production of biofuels in Latin America. The objective of this 'Research and Technology Development Roadmap for Biofuels in Latin America' is to present a set of RTD needs on biofuels to boost biofuel production in LA, to provide a mechanism to foresee biofuel developments in LA, and to provide a framework to communicate and coordinate biofuel developments. This roadmap identified priority areas for (public and private) RTD efforts. Thereby, this roadmap includes proposed RTD timeframes and highlights specific research topics in order to close knowledge gaps that hinder an effective development path of biofuel technologies in Latin America. In total, six roadmaps for the following conversion technologies were developed: first generation bioethanol, second generation bioethanol, pure plant oil (PPO) and biodiesel, biomethane, Biomass-to-Liquids (BtL) fuels, and biorefineries. Finally, synthesised country-specific roadmaps were developed for Argentina, Brazil, Chile, Mexico, and Colombia. An example for a country-roadmap (Brazil) is shown in.

In conclusion, it is believed that enhanced RTD cooperation between stakeholders from Latin America and Europe on abovementioned topics will contribute to an increased deployment of biofuel technologies in Latin America and ensure the future sustainable development of the biofuel sector in Latin American countries.

Recommendations

Finally, recommendations on policies and future cooperation opportunities between RTD organisations in Europe and Latin America were developed. The objective was to give recommendations on concrete RTD cooperation opportunities within the three research areas of biofuel conversion technologies, sustainable...
Cooperation opportunities within the three research areas of biofuel conversion technologies, sustainable biofuel production, and biofuel standardisation and trade. In parallel, policy recommendations were elaborated with the objective to give advice on how research and development in the field of biomass conversion technologies could be supported in Latin America and Europe. They provide a profound background for European decision makers, funding bodies and donors, including the European Commission, to efficiently allocate resources to the most promising RTD activities.

BIOTOP events

In the framework of the BIOTOP project, a variety of cooperation events were organised at different levels and for different target groups. This included three international workshops, an international stakeholder consultation meeting, four study tours, several seminars and meetings at local/regional level, courses and student exchanges within the RTD exchange programme, and the final international BIOTOP conference. Thereby, more than 1,000 participants were registered showing the high interest of biofuel stakeholders in EU-LA cooperation. All presentations held at BIOTOP events are available for download at the BIOTOP website.

- EU-LA biofuels workshop on sustainability in Sao Paulo, Brazil
- EU-LA biofuels workshop in Buenos Aires, Argentina
- EU-LA biofuels workshop in Valparaiso, Chile
- EU-LA stakeholder consultation meeting in Lyon, France
- Regional stakeholder campaigns in Argentina, Brazil, Chile, and Mexico
- Technical tours in Germany, Argentina, Chile, and Spain

BIOTOP RTD exchange programme

In the framework of BIOTOP several exchange activities between Uni Graz, UCV, UNAM, and WIP have been organised. All RTD exchange activities are summarised in the BIOTOP report ‘RTD Exchange Programme for Biofuels between Europe and Latin America’. This report also includes an outlook on future cooperation and a draft joint syllabus for an international EU-LA Course on Biofuels.

EU-LA cooperation conference in Brussels, Belgium

An International Conference on 'Biofuels in Latin America and Europe' was organised as final event of the BIOTOP project. The conference took place at the 'Novotel Brussels Centre Tour Noire' in Brussels, Belgium, on 13 - 14 July 2010. More than 90 participants attended the conference. The conference agenda is presented in the report ‘Summary of the International Conference on Biofuels Cooperation: Latin America and Europe in Brussels’.

Stakeholder consultation and project dissemination

The BIOTOP project activities and results were disseminated among various stakeholders. BIOTOP actively promoted the exchanges between RTD experts, stakeholders and key actors and it supported consultation and integration of stakeholders in project activities.
Contact details of more than 1,500 stakeholders and experts were identified in order to facilitate research cooperation and to disseminate project activities. The BIOTOP Associate Membership serves as mechanism of stakeholder involvement and interplay with stakeholders from all Latin American countries. Interested stakeholders had the opportunity to join the 'Latin American Biofuels Cooperation Platform' by applying as BIOTOP Associate Members.

A project website was developed (see http://www.top-biofuel.org online) and continuously up-dated. All publishable reports, workshop presentations, and dissemination material were uploaded on the website. BIOTOP events, such as workshops and study tours, were announced on the website.

Actual developments, results, and announcements were published in five BIOTOP newsletters, issued every six months.

Project activities and results were furthermore presented and disseminated on several occasions in LA and Europe. This included oral and visual presentations, distribution of printed project leaflets, and articles in magazines and journals. The following list shows project presentation activities:

Potential Impact:

The general objective of BIOTOP was to create and support Research and Technology Development (RTD) cooperation activities in the biofuels sector between Latin America and the European Union. The specific objectives were twofold: firstly, to foster the collaboration between European and Latin American stakeholders in the production of biofuels by identifying priority RTD needs and opportunities; and secondly, to increase awareness among European and Latin American stakeholders about technical opportunities and the large potential of biofuel production in LA.

BIOTOP successfully increased RTD cooperation between the two continents in the field of biofuels. Cooperation among individual researchers and institutions was stimulated by the organisation of several events, involving more than 1,000 participants from both continents. Joint courses and exchange visits contributed to this success and facilitated the establishment of common courses and RTD exchanges. The involved universities committed themselves to continue inter-continental research. A good opportunity to continue these activities is given by the opening of FP7 calls to all Latin American countries, which can jointly apply with European partners for research funds. However, it is proposed that dedicated calls for EU-LA cooperation are launched, in order to deepen the cooperation.

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http://www.top-biofuel.org

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