Module 4.6

Biofuel Production

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1 General Introduction

Bioenergy can be in the form of liquid biofuels such as ethanol, biodiesel and straight vegetable oil, used in internal combustion engines, mainly in the transport sector. Liquid biofuels consumption has been rising significantly over the last decades mainly driven by national and regional policies in the form of biofuel targets and blending mandates, with the following aims:

- To **mitigate climate change** providing an immediate available and cost-effective manner to reduce GHG emissions. Liquid biofuels are compatible with the current fossil fuel infrastructure. This means that they can be blended with fossil fuels and make use of the same infrastructure with minimal adaptations[1] (they can be used in traditional car internal combustion engines, in aeroplanes, in large boats, in tank stations, etc). There is no other renewable energy option that can substitute fossil fuels without major additional investments in infrastructure, thus contributing to GHG emission reduction.
- To ensure and increase **energy security**. In fact, the dependency on a highly volatile market like the fossil fuel one, together with geo-politic concerns linked to energy dependency of certain states from other states, can negatively affect developed and developing economies alike. However the poorest, relying on fossil fuels for their day-to-day life or for productive activities, are those who would be hit the most by a shock of fossil fuel prices. Therefore the dependency from the fossil fuel market should be reduced.
- To **promote sustainable development** diversifying agricultural production. Biofuels are usually produced from energy crops, which can from one side offer another market to farmers to diversify their reference market, and the same time it is expected to leverage the required investments and knowledge needed for agriculture development in poor regions.

A number of concerns have been voiced regarding potential impacts on food security and the environment related to the rapid expansion of bioenergy feedstock production, and in particular, competition between different land uses (FAO-UNEP 2011) competing for the same natural resources.

Although the majority of traditional biomass in developing countries is burned in solid form, use of biogas and the production of liquid biofuels, or feedstock for the production of biofuels, has expanded considerably. Liquid biofuels met about 2.3% of global transport fuel demand and reached 116.6 billion litres in 2013 (Global Statut Report (GSR) 2014, REN21). Total biofuel consumption in the EU represented about 4.7% of transport fuel consumption in 2010, mainly first generation (1G) biofuels (see section 3).

The globe has about 13200 Million ha of land of which about 1600 Million ha is used for growing various crops. Less than 3% of global cropland is used to produce biofuels. The EU uses around 2% of agricultural land for biofuels (EC 2012).

[1] Biofuels have different caracteristics if compared with the fossil fuels they substitute in terms of lubricity, cetane and octane number, viscosity and ultimately on engine performance. Certain internal combustion engines for example cannot run just on biofuels but they can be blended with fossil fuel up to a certain percentage. Technologies exist such as in Flexible-fuel cars, very common in Brazil, which can adapt the burning caractheristics of the engine (changing fuel residence times) to the fuel in the tank, ethanol or gasoline in this case.

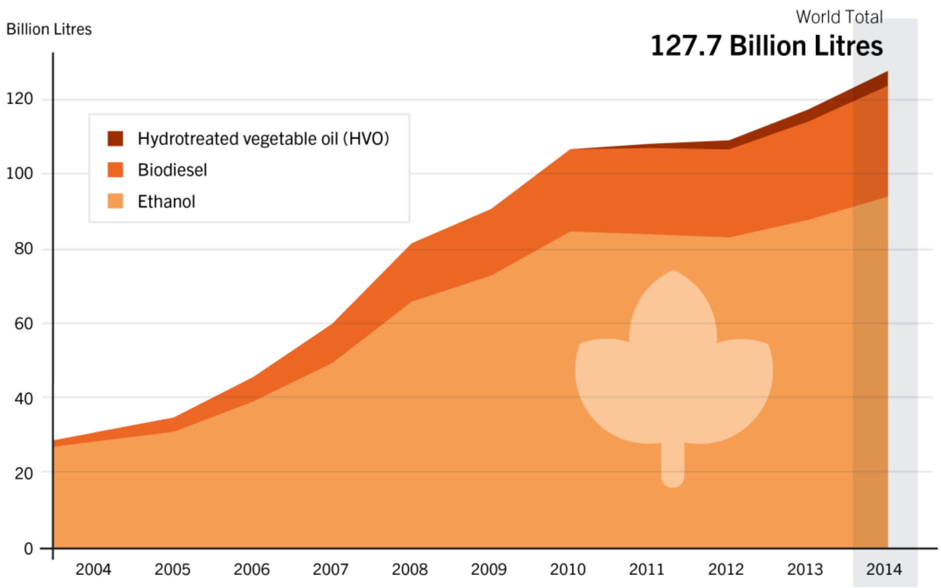

Figure - Trends of HVO, biodiesel, ethanol global production

Source: REN21 Renewables 2015 Global Status Report

Liquid biofuels for transport are produced in several countries worldwide and from a large variety of feedstocks, but the main producing countries and feedstocks today are limited to just a few (see figure below).

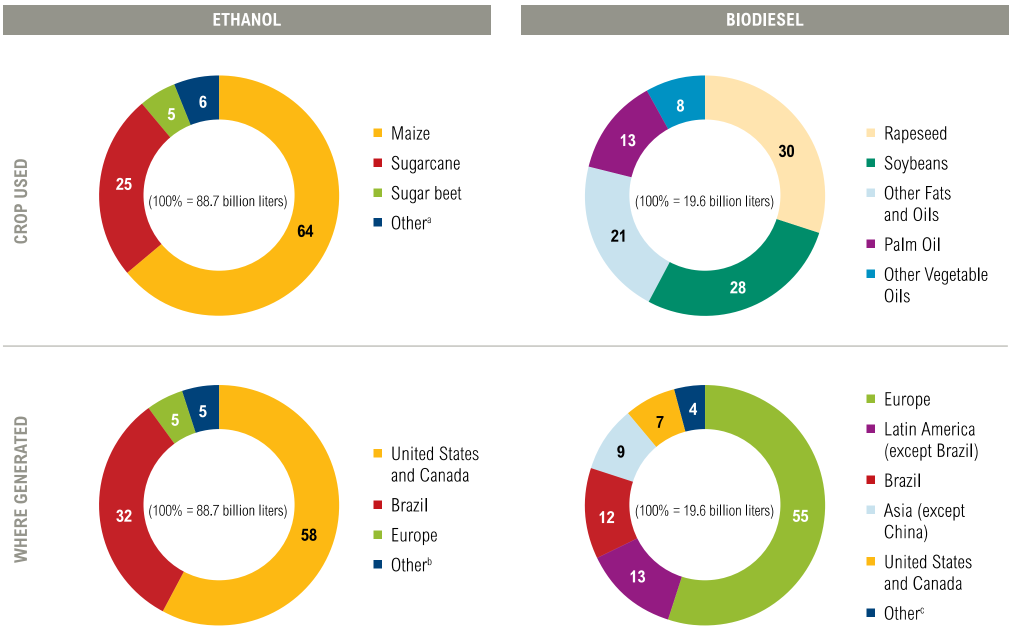

Figure – Liquid biofuel production in 2010

Source: World Resources Institute (WRI), 2015

The demand of liquid biofuels for transport is increasing worldwide and this is mainly due to the minimum quota and blending mandates which have been introduced in a number of countries. The table below summarizes the existing targets by country.

In the EU, biofuel use is directly promoted through:

- the Renewable Energy Directive 2009/28/EC(RED) which sets rules for the EU to achieve 20% renewables target by 2020. It also mandates that 10% of the transport fuel of every EU country come from renewable sources such as biofuels (only part of this from energy crops which can also be used for food. The rest from advanced biofuels[2]); and
- the Fuel Quality Directive2009/30/EC which requires a reduction of the greenhouse gas intensity of the fuels used in vehicles by 6 % by 2020. This legislation, the Fuel Quality Directive, also regulates the sustainability of biofuels. According to the Directive, GHG emissions must be at least 35% lower than from the fossil fuel they replace. From 2017, this will increase to 50% and, from 2018, the saving must be at least 60% for new installations; and the raw materials for biofuels cannot be sourced from land with high biodiversity or high carbon stock.

In 2010, 83% of the biofuels consumed in the EU were produced in the EU, part of which is produced from imported feedstock. The main countries exporting biodiesel to the EU were Argentina, Brazil and USA for soy biodiesel and Indonesia and Malaysia for palm oil. For bioethanol, the main exporting countries were Brazil for sugarcane bioethanol and the USA for maize bioethanol (EC 2012).

2 General principles

Biofuels or biofuel feedstock are produced mainly for export and are sometimes seen as a new market (creating jobs, attracting foreign investments, etc);or they are used locally to meet national blending mandates (like in the case of Senegal) or used as refined fuels (e.g. ethanol, gels) for cooking.

Modern bioenergy can transform the agricultural sector by providing additional roles to the existing ones of being the guarantor of resource use efficiency and the basis of rural livelihoods. The expansion in bioenergy closely links the agricultural sector to the industrial sector.

Biofuels can be produced following several pathways, but they are usually produced from dedicated energy crops. The potential of energy crops as biofuel feedstock vary significantly between areas and within areas, as do the production/ collection and conversion costs and the end products they can be used for. Each source has its specific advantages and disadvantages.

The theoretical potential for energy crops in many regions is large, but can be limited by land and water availability as well as competition for other uses (food, feed, fibre). The potential environmental and social impacts from the production of dedicated energy crops differ also depending on the management system.

[2] Advanced Biofuels are those (1) produced from lignocellulosic feedstocks (i.e. agricultural and forestry residues, e.g. wheat straw/corn stover/bagasse, wood based biomass), non-food crops (i.e. grasses, miscanthus, algae), or industrial waste and residue streams, (2) having low CO_2 emission or high GHG reduction, and (3) reaching zero or low Indirect Land Use Change (ILUC) impact.

Box: The case of Jatropha

In the early 2000s, Jatropha was rediscovered as a suitable oil crop for the production of vegetable oil for biofuel. The plant was generally thought to thrive on poor soils with a minimum of water and nutrients, and still produce large quantities of oil-bearing seeds. Although the basis of these claims was thin, hundreds of jatropha projects were started worldwide, and millions of USD were invested.

After a few years, most projects showed marginal yields, and the initial hype ended and the reputation of jatropha was seriously damaged. The lessons learned is that it is true that Jatropha can grow in semi-desertic areas, difficult conditions, and using little water, however, in these conditions, the yields are not enough to make it commercial and competitive with other feedstocks. Only recently, research seems to have resulted in species that produces the desired quantities of seeds, albeit under well-managed conditions, and possible valuable uses of the by-products. However the fact that Jatropha is a poisonous non-domesticated plant still poses several challenges to be overcome.

Biofuels can be used for:

- The provision of transport fuels includes various options with respect to technical specifications (fuel vehicle compatibility) and marketability. Currently, main transportation fuels are ethanol and biodiesel. However, depending on circumstances and envisaged end use, straight vegetable oil (SVO) can be an option too. It is also possible to produce other fuels through more advanced processes (e.g. methanol or Ethyl tert-butyl ether - ETBE)
- Mechanical power at different scales. Small industries and farmers can make use of biofuels to run internal combustion engines for a number of mechanical processes, such as grinding or milling on farm.
- Cooking and heat at household level. Ethanol can be used for cooking and heating in improved cookstoves, in pure for or as gel fuel.

3 Technology overview

Feedstock	Conversion process	Energy vector	End use	Typical scale range
Sugar/starch	Fermentation and/or distillation	Fuel (Ethanol)	Automotive	>30,000 GJ/year
		Heat fuel (Ethanol)	Domestic	1-10 kW_{th}
Vegetable oils / animal fats	Extraction	Straight Vegetable Oil (SVO) (electricity)	Industry, farms or domestic	5-100 kW
		Straight Vegetable Oil (SVO) (mechanical power)		5-100 kW
	Extraction / transesterification	Biodiesel	Automotive	>100,000 GJ/year

Table - Relevant biofuel technologies and fuels

The most common technology pathways and biofuels are reported below.

Ethanol fuel

Ethanol is a colourless, volatile and highly inflammable liquid that can be used as a fuel in spark plug engines, either in a blend with gasoline or as a heat fuel. It is produced by fermentation of sugars and starch (after hydrolysis); the (low concentration) ethanol thus produced can be purified to 96% through distillation, and subsequently dried to more than 99% using molecular sieves or membranes. Second-generation technologies are under development and they can convert celluloses into ethanol, after physical / chemical pre-treatment of the feedstock and subsequent enzymatic conversion of the cellulose into fermentable sugars.

Ethanol is traditionally produced from sugars (sugar cane, sugar beet, sweet sorghum, molasses, fruit pulp etc.) and from starches (maize, cassava, wheat etc.). Cellulose materials for second generation ethanol production include a variety of materials such as bagasse and rice straw.

Advantages

- Ethanol is one of the few available renewable transportation fuels
- Ethanol production is a well-known and technology is commercially available. There exist several international norms regulating the required properties of the ethanol for fuel use.

Disadvantages

- Ethanol production can be costly, unless done on a large scale (>10,000 tons per annum (t/a)) and/or from readily available feedstocks
- Some feedstocks have a high value as foodstuff (sugar, cassava, maize etc) which make them more expensive for ethanol. At the same time, ethanol production could lead to food market distortions
- Higher gasoline-ethanol blends, and use of neat ethanol, require adapted engines.

The demand for liquid transportation fuels is huge, and any possible opportunity for substitution could be relevant.

Ethanol can further be processed into **ethanol gelfuel** to be used in clean Cookstoves (see module 'Clean cooking systems and biogas').

Straight Vegetable Oil (SVO)

SVO is a liquid fuel that can be used as a (partial or total) replacement of diesel fuel in diesel engines. In most cases it concerns oils that are cold pressed from oil bearing seeds using an oil expeller. The oil is then filtered; further refining is often required to reduce fatty acids, phospholipids and water. Shelf life of SVO is limited as it tends to oxidise and polymerise over time. SVO is different from biodiesel, which is chemically processed.

SVO can be used as a single fuel in diesel engines, but needs to be pre-heated in order to reduce its viscosity. This is typically done using engine heat, but this does require an adaptation of the engine. Some types of SVO can be blended with diesel to a degree that sufficiently reduces its viscosity, and can then be used in engines without modification.

Common types of vegetable oils include palm oil, soy bean oil, sunflower oil, coconut oil, cottonseed oil, jatropha oil, and waste vegetable oil. It is important to note that all but the latter two types are edible and may fetch a better price as foodstuff. Palm oil is by far the highest yielding type of vegetable oil (in tons of oil per hectare).

Advantages

- SVO has properties that are similar to fossil diesel, and can be mixed with diesel to be used in (existing or modified) diesel engines.
- SVO driven diesels are suitable to power mini-grids, either solely or in combination with other (renewable) energy sources.

- SVO can be produced in rural areas; in remote areas, where diesel prices are high, and it can be financially attractive to replace diesel with locally produced SVO. In such areas its production can be an interesting income-generating activity.
- The technology for SVO production and use is not very complex, and can be applied on small and larger scales.

Disadvantages

- In some cases, production costs of SVO may not differ much from diesel price making it difficult to compete.
- In most cases the market value of edible vegetable oils – the alternative for fuel use – sets a relatively high price level for SVO.
- Under certain conditions, the use of vegetable oils for fuel can lead to distortions in the local food market and hence affect food security.

SVO is a diesel fuel substitute that can add to the energy self-sufficiency of remote areas, where diesel prices are high and vegetable oil prices are low. Production of seeds and processing into oil can introduce new economic opportunities for farmers and small businesses.

Biodiesel fuel

Biodiesel is the product of transesterification of vegetable oil using an alcohol (usually methanol) and a catalyst (e.g. potassium hydroxide or methylate). The process results in the transformation of triglycerides into their respective fatty acid esters and free glycerol. The esters are the actual biodiesel, which, after removal of the glycerol and of any process by-products, can be used as a diesel fuel substitute, either in a blend with fossil diesel or as a neat fuel. The viscosity of biodiesel is close to that of fossil diesel; no engine modification is required, although the strong solvent function of the biodiesel may liberate any deposits that may have built up by the engine during its life.

Biodiesel production is a chemical process that requires properly engineered installations and a thorough understanding of the process, its inputs and its outputs. Small scale production is possible but is usually less efficient, and often results in poor quality biodiesel at high costs. Approximate minimum production scale for feasible operation is 5,000 tons per annum (t/a).

A large range of oils and fats can be used as raw material for biodiesel. Most commonly used oils include palm oil, soybean oil, cotton oil, rape seed oil, and waste vegetable oil. Although very low quality oils can be used, their conversion efficiency is very low.

Advantages

- Biodiesel is one of the few available renewable transportation fuels
- Use of biodiesel does not require any engine modifications

Disadvantages

- Biodiesel production is an industrial process that requires intimate knowledge of the conversion process and the properties of the raw materials
- Biodiesel produced at too small a scale may not be competitive with fossil diesel.
- Although the main input (oil) is often locally available, the chemicals (methanol, methylate) usually have to be imported which adds to the costs

Typically only the sugar or starchy part of the biomass is converted into liquid fuels through fermentation and/or distillation. The conventional and well establish technologies which transform this non ligneous biomass into ethanol or other fuels are often referred to as **First Generation (1G) biofuel technologies**.

However, a number of innovative technologies are under research, development and demonstration phases, able to convert also part of the ligneous and cellulosic part of the biomass into fuels. This makes possible to use largely abundant plants, which are usually non-food crops, for the production of liquid biofuels. Lignocellulosic biomass conversion technologies (usually referred to as **Second Generation (2G) biofuel technologies**) are not commercially widespread yet, and worldwide there are only a bunch of commercial experiences (the first commercial second generation biofuels production plant in Europe became operative in 2012 in Italy). In principle all conventional feedstocks can be converted with 2G technologies, hence increasing the useful energy which can be produced from one unit of biomass, and many more lingo-cellulosic feedstocks can be converted with 2G technologies, including fast growing grasses.

Algae can also be used as a feedstock to produce bioenergy, including liquid biofuels. Algae are fast growing organisms which are largely available in some areas and can undergo a number of conversion processes (the most promising one are probably hydrothermal processes, which are not ideal for the production of liquid biofuels, but rather syngas or charcoal). Over the last years an important wave of research was dedicated to research and development for the production of liquid biofuels from algae with good results, but still far from making this a viable and commercial option for large-scale biofuel production from ad-hoc plants (the so-called **Third Generation (3G) biofuel technologies**). Algae can be divided into microalgae and macroalgae (seaweed). The main problem is associated with the upscale of the lab or demonstration experiences, as production concepts which work at small scale then become unmanageable or excessively costly when the production needs to reach a larger scale to become commercial. R&D and mostly Demonstration are still underway in this domain, mainly in Europe and in the US with encouraging results.

2G and 3G or advanced biofuels are produced from feedstock that do not compete directly with food and feed crops (e.g. wheat straw, municipal waste, miscanthus, short rotation coppice) and algae.

In principle several technologies can be applied to the same biomass feedstock to obtain the desired energy service (or the desired energy carrier). The possible conversion routes are multiple, and a list of them would never be exhaustive. Many pathways are still in the research, development or demonstration phase (see the figure below to have an idea of some of the possible biofuel conversion pathways). More advanced technologies tend to have higher conversion efficiencies, but higher capital cost as well. Furthermore, an efficient technology does not work effectively if there is no human capacity to absorb it, run it, and maintain it. Trade-offs may have to be made in order to find the best technical solution that is viable in a specific country context.

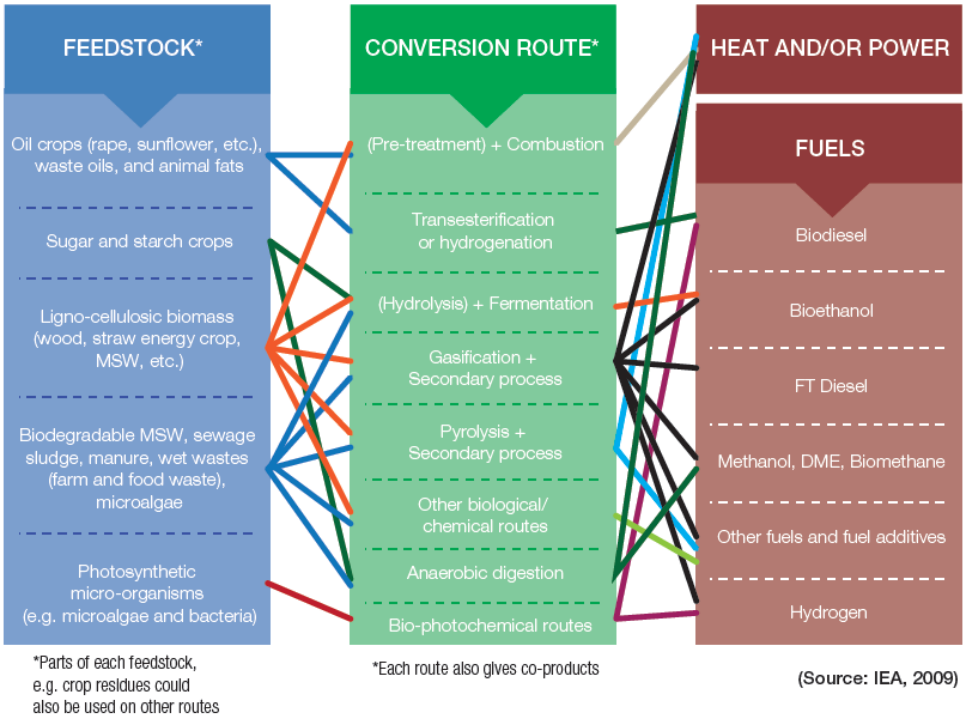

Figure - Biofuel conversion routes

Source: FAO/UNEP 2012

4 Typical Benchmarks

The tables below summarize the current costs of the main liquid biofuel technologies associated with their characteristics.

Fuel	Density (kg/m³)	Lower heating value (MJ/kg)	Production costs (cents USD/liter)	Production cost for diesel or gasoline equivalent (Cents USD/liter)
Ethanol	794	26,81 (gasoline: 29,7)	Sugar cane: 74–84 (Brazil) Corn (dry mill): 76–115 (United States)	Sugar cane: 82–93 (Brazil) Corn (dry mill): 85–128 (United States)
Biodiesel	860-900	37 (diesel: 43,4)	Soybean oil: 48-61 (Argentina); 85–102 (Global average) Palm oil: 85–110 (Indonesia, Malaysia, and other) Rapeseed oil: 89–110 (EU)	Soybean oil: 56–72 (Argentina); 100–120 (Global average) Palm oil: 100–130 (Indonesia, Malaysia, and other) Rapeseed oil: 105–130 (EU)
Crude vegetable oil	900-950	37 (diesel: 43,4)	60 (United States) 65 (Tanzania)	70 (United States) 76 (Tanzania)

Table – Typical characteristics and costs[3] of main fossil fuels

Source: REN21 Renewables 2015 Global Status Report, Biograce and other sources

[3] The costs are site specific, as many of these components can vary according to location.

5 Economic and environmental impact

The huge technical and economic potential of bioenergy in several regions, including the African continent, can be significantly limited by environmental and social (mainly food security) sustainability constraints. Water and land resources will be increasingly over pressure in the future, as these are limited resources that should be used to satisfy a number of human needs and to provide a number of environmental services. A sound water-energy-food nexus assessment is needed when dealing with such a cross-cutting issue like biofuel feedstock cultivation. There are however a number of good environmental practices identified which help minimize the negative effects on soil, water, biodiversity resources, GHG emissions, as well as socio-economic aspects (see BEFS 2011. Good Socio-economic Practices in modern Bioenergy Production. http://www.fao.org/docrep/015/i2507e/i2507e00.pdf and FAO, 2012. Good Environmental Practices in Bioenergy Feedstock Production.www.fao.org/3/a-i2596e.pdf).

It is noteworthy that the benefits, impacts and costs tend to vary across commodities, business models, and landscapes, making findings from industrial-scale bioethanol production in Brazil, for example, different from the impacts associated with oil palm in Indonesia or Jatropha cultivation in sub-Saharan Africa, each of which is expanding through both smallholder and industrial-scale production models. Such differences are often obscured in the controversial discussions that have characterized this emerging industry. There are key arguments made for and against biofuel expansion, with a focus on the local social and environmental impacts especially for small-scale farmers' households (AETS Consortium, 2013).

Positive impacts include:

- Job as an employment creation either in the processing plant or in the field;
- Additional incomes due to producing and selling feedstock;
- Creation of jobs in a related service industry (e.g. tractor repair shop);
- Better access to agro-input supplies, such as seeds, machinery, agro-chemicals and even agro-financing;
- Technology and knowledge transfer and training;
- Improved access to energy for productive activities, leisure, which provides the opportunity to start new businesses in off-grid areas;
- Achievement of energy security and stimulation of rural economic development through employment and smallholder market integration.

Negative impacts include:

- Risk for smallholders to lose their land due to unclear land tenure systems and the increased interest in agriculture production;
- Destructuration of the local communities and traditional balances of power;
- Depletion of water resources due to production and processing of biofuels;
- Pollution from overuse of agro-chemicals for feedstock production and chemicals for the conversion process;
- Failed biofuel investment projects have negative impacts on farmers; often farmers lose their land during the preparation of the investment, the landscape is no longer available for local agriculture and pastoralism; and – due to the failure of the project– no potential benefits occur, such as jobs, revenues or infrastructure.
- Soil depletion due to over production of energy crops. The risk arises in particular when residues are not managed properly and too little residues are left in the field. In facts,

agricultural and forestry residues which are not used to other purposes are usually used for soil improvement and fertilisation of fields. Removal these residues for energy purposes without compensating the loss of nutrients eventually leads to soil depletion, especially in arid or semi-arid areas.

The relationship between biofuel production and deforestation is very complex and difficult to quantify (CIFOR, 2011): no global deforestation data and global biofuel feedstock plantation data are available of sufficient resolution. However there are very recent models able to assess the renewable and non-renewable biomass fraction, based on GIS.

It is generally accepted that bioenergy from energy crops (both food and non-food crops) has the potential of either increasing or reducing food security (especially for smallholder farmers) depending on the policy behind its development and the characteristics of the local agricultural sector. The effects of bioenergy (in particular liquid biofuels) development on national food security can be significantly different for a net exporter or a net importer of food and agricultural commodities (AETS Consortium, 2013).

Most land acquisitions are linked with free access to water sources and sometime exclusive control over the water resources, when the increasing scarcity of water must be recognized. Besides the high water requirements for the cultivation and processing, the supposed free water use by biofuel investors leads to inappropriate water footprint (inefficiency, waste and pollution). The uses of water to produce energy and the uses of energy in water supply and sanitation (water-energy nexus) are not always taken into consideration.

The principal critique relative to agricultural investment in developing countries deals with the so-called "marginal" land which could be used to grow biofuel feedstock. In fact, in most cases, land is already being used or claimed – yet existing land uses and claims go unrecognised because land users are marginalised from formal land rights and access to the law and institutions (AETS Consortium, 2013).

There are several instruments that aim to encourage corporate social responsibility (CSR) among companies. In terms of relevance to conventional biofuel production, the most relevant ones can be found within commodity specific instruments, as well as general CSR instruments. Compliance with such instruments or commodity certification schemes is voluntary and they usually lack remedy mechanisms. Other instruments to ensure sustainability include certification schemes and sustainability standards, such as those recognized by the EU for biofuels which account towards the achievement of the EU RED objectives. A complete list of current voluntary schemes is available here: https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/voluntary-schemes.

Indeed, certification and the development of a tracking or chain of custody system for bioenergy feedstock and products can be a natural next step for all regulators.

Since any certification comes with a cost associated, it is important to ensure that smallholders do not need to bear a too high compliance cost. Therefore, it is essential to simplify the sustainability requirements where necessary, or by enabling group certification.

The main environmental impacts of feedstock production for energy crops are caused by intensive farming systems, cultivating crops with high input levels, which are both natural (land, soil, water, native vegetation) and agrochemical. Large scale systems used for food crops production may be more efficient but not always sustainable.

A key factor in the analysis of the impacts of biofuels development is the type of production system: large-scale plantations; small-scale liquid biofuel farms (contract farming); small-scale local energy farms for local energy power needs; hybrid model (a mix of plantation and out grower).There is no "best" scheme because the conditions must be considered on a case-by-case basis. In fact, the size of the bioenergy project (in terms of area, capital invested, jobs created) alone does not tell much about its sustainability or ability to contribute to sustainable development. The targeted bioenergy market (or the end-users), the nature and the kind of contract arrangements between farmers and the project initiator (i.e. small scale projects for local energy access, commercial farmers producing biofuels for own consumption, out grower farming schemes, large plantations employing farmers directly) appear more relevant for an appraisal of the direct contribution towards sustainable development.

The FAO Bioenergy and Food Security (BEFS) project identified a number of good socio-economic practices in modern bioenergy production, which can minimize risks and increase opportunities for food security (BEFS, 2011). They include:

- Good Practices to Safeguard Access to Land for Local Communities (Consultation; Mapping of customary land rights; Fair compensation to landowners/users; Conflict resolution mechanisms; Inclusion of smallholders in bioenergy supply chain);
- Good Practices to Ensure Decent Work (Adherence to: ILO Declaration on Fundamental Principles and Rights at Work and related Conventions, ISO 26000 - Social Responsibility, Social Accountability (SA); Living wage)
- Good Practices to Promote Income Generation and Facilitate the Inclusion of Smallholders (Contracts with local goods and service providers; Freedom of association and collective bargaining; Access to credit; Fair and transparent pricing; Profit sharing; resolution mechanisms)
- Good Practices to Safeguard or Enhance Local Food Security (Integrated Food and Energy Systems; Subsistence plots; Provision of improved agricultural inputs and/or equipment; Trainings on good agricultural practices; Provision of food; Improved cookstoves)
- Good Practices to Enhance Community Development (Development or improvement of local infrastructure; Training and education programmes; Health and safety equipment/devices and information; Microlending and financial support mechanisms)
- Good Practices to Increase Energy Security and Local Access to Energy (Development or improvement of energy infrastructure; Provision of energy for local and/or domestic use; Improved cookstoves)
- Good Practices to Ensure Gender Equity (Gender-sensitive corporate conduct; Gender-related corporate policies and programmes; Women in leadership positions)

Associated with these good practices, the project produced a compilation of the specific policy instruments that could be put in place to promote such good practices (see BEFS, 2012 "Policy Instruments to Promote Good Practices in Bioenergy Feedstock Production" for more info).

Last but not least, the positive environmental impacts of bioenergy and biofuels (and actually the major driver for fostering bioenergy in developed countries) is linked to the minor Green House Gas (GHG) emissions in comparison with fossil fuels. Again, GHG reduction can vary significantly depending on the specific pathway, the end product and, even more importantly, on where (on which land and using which practices) the bioenergy feedstock is produced. For example, in order to account towards the EU RED objectives, biofuels should emit at least 35% less GHG than their fossil fuel equivalent[4]. GHG reduction of biofuels should be considered from a life-cycle perspective, and it is up to the producer to calculate and demonstrate the emissions associated with their production. If the calculation is not possible or there is no capacity to measure the exact GHG emissions, the EU

[4] Minimum GHG reduction required will increase in the future, as previously mentioned: from 2017, this will increase to 50% and, from 2018, the saving must be at least 60% for new installations.

RED provides a number of default emission factors for most part of biofuel produced under different conditions (see Annex V of the EU RED here: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0028). As it stands, 1G ethanol, especially Brazilian ethanol, and 2G and 3G biofuels (lignocellulosic, or advanced biofuels such as algal biofuels) are particularly favoured under the EU RED.

Critics to the current EU biofuel policy have been made and these are linked to two main issues:

- In the calculation of GHG actually saved by biofuels, indirect land use (ILUC)[5] is not taken into considerations and this factor could significantly change the results. To date there is no convincing method to assess indirect land use change, even if many attempts and methodology have been developed around the world. As such, with an holistic approach including iLUC, the real GHG savings of certain biofuels the EU is promoted could even be negative thus neglecting any benefit in terms of climate mitigation.
- The actual impact on food security of producing biofuels from energy crops which could be used also for food (e.g. sugarcane, rapeseed oil, soybean, sunflower, etc.) is unclear and many different figures have been suggested over the years. Today there is still no agreement about how to measure the impacts and if there is any impact. This affects mainly poor countries exporting biofuel feedstock or biofuels and chiefly South-East Asia and sub-Saharan Africa. The only internationally agreed indicator to measure the impacts of bioenergy on food security is Global Bioenergy Partnership (GBEP) indicator 10 "Price and Supply of a National Food Basket" (GBEP 2011) which is currently being piloted in a number of countries. As a precaution, the European Parliament's environment committee in February 2015 backed a new limit on traditional biofuels made from food crops to 6%, which is slightly higher than current use of biofuels made from food crops (this debate is still ongoing).

6 What are the key questions?

Environment and natural resources: potential impacts to ecosystems, biodiversity, water, forest resources and products, soil, GHG balances, and air quality

- Will biofuel production directly affect any rare or threatened ecosystems or habitat types through conversion, habitat loss or fragmentation?
- Will biofuel production lead to a reduction in soil productivity?
- Will biofuel production result in the introduction of non-endemic invasive species?
- To what extent will biofuel production adversely impact water availability and/or quality both for downstream ecosystem processes and services and for downstream human activities and domestic uses (both current and projected)?
- Will the GHG savings be positive or negative compared to the fossil fuels displaced?
- Are sufficient land and water resources locally available?
- Which are the most suitable crops and the most adequate modes of cultivation?

[5] When biofuels are produced on existing agricultural land, the demand for food and feed crops remains, and may lead to someone producing more food and feed somewhere else. This can imply land use change (by changing e.g. forest into agricultural land), which implies that additional CO_2 emissions are released into the atmosphere.

Socio-economic effects: land tenure and displacement risk, income generation, potential exclusion of certain groups/individuals, employment, labour conditions, increased energy access, local governance

- To what extent will bioenergy production lead to the displacement of local communities or of certain groups/individuals (particularly vulnerable groups such as indigenous communities and women) within them?
- Will the opportunities associated with bioenergy production be equally distributed across groups and individuals?
- Will bioenergy production generate more jobs than it will replace?
- To what extent will the bioenergy produced (or part of it) be used to meet the local demand for energy?
- Is bioenergy production profitable without explicit and implicit subsidies? In the short, medium and long run?
- What action can the local population take in case of bad performance of local government/local line agencies/economic operators?
- What is the amount of biomass resources which can be made practically and economically available?
- Is there a market for by-products?
- How are local tenure rights managed?
- Are specialized skills available, including knowledge of modern farming practices?
- Are there fossil fuel subsidies that make traditional energy sources artificially cheap?
- Which sustainability requirements should the feedstock or biofuel produced comply with and what is the associated compliance cost?

Food security impacts: food availability, access, stability and utilisation

- What is the status of food insecurity (chronic and transitory)?
- What are the main staple foods in the diet of the country's poor and vulnerable populations?
- To what extent will bioenergy production affect the availability of the key staple crops - now, throughout the year, and in years to come?
- To what extent will increased demand for agricultural commodities for bioenergy production affect the prices of key staple foods? At the national level? In the local area?
- How will increased use of agricultural inputs for feedstock production affect input availability for food production? Now, and in the future?
- Do safety nets exist to protect against temporary food insecurity?

7 Some useful references

Good environmental, and socio-economic practices for bioenergy feedstock production

AETS Consortium, 2013. Assessing the impact of biofuels production on developing countries from the point of view of Policy Coherence for Development. http://ec.europa.eu/europeaid/sites/devco/files/study-impact-assesment-biofuels-production-on-development-pcd-201302_en_2.pdf

FAO, 2012. Good Environmental Practices in Bioenergy Feedstock Production - Making Bioenergy Work for Climate and Food Security. www.fao.org/3/a-i2596e.pdf

BEFS, 2012. Policy Instruments to Promote Good Practices in Bioenergy Feedstock Production. http://www.fao.org/uploads/media/1203_BEFSCI-FAO_Policy_instruments_to_promote_good_practices_in_bioenergy_feedstock_production.pdf

BEFS, 2011. Good Socio-economic Practices in modern Bioenergy Production. http://www.fao.org/docrep/015/i2507e/i2507e00.pdf

Sustainable bioenergy tools

FAO BEFS Rapid Appraisal Tools:

- Country Status: http://www.fao.org/energy/befs/86186/en/
- Natural Resources - Biomass Potential Assessment (including Land Suitability Maps): http://www.fao.org/energy/befs/86187/en/
- Energy End-use Options - Techno-economic and Socio-economic Analyses: http://www.fao.org/energy/befs/86188/en/

FAO/UNEP, 2012.A Decision Support Tool for Sustainable Bioenergy. http://www.bioenergydecisiontool.org/overview/Overview_content_web.pdf

GBEP, 2011. The Global Bioenergy Partnership Sustainability Indicators for Bioenergy, First edition – Executive Summary. www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/Indicators/GBEP_Report_Indicators_Executive_Summary.pdf

The FAO Support Package to Decision-Making for Sustainable Bioenergy: http://www.fao.org/energy/82318/en/ including: the Decision Support Tool for Sustainable Bioenergy (DST), Bioenergy and Food Security (BEFS) Approach, the Bioenergy Environmental Impact Assessment Framework (BIAS), the GEF biofuels project screening toolkit, the BEFS Operator Level Tool.

EU policy and implementation

Information on the Fuel Quality Directive: http://ec.europa.eu/clima/policies/transport/fuel/index_en.htm

Information on the Renewable Energy Directive: https://ec.europa.eu/energy/en/topics/renewable-energy

EC, 2009. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC

Information on the new (lower) EU cap for biofuels produced from food crops: http://www.euractiv.com/sections/energy/eu-lawmakers-back-6-cap-food-based-biofuels-312398

Information about current voluntary schemes recognized by the EU towards the objectives of the RED: https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/voluntary-schemes.

Information about indirect land use change in the EU and related issues (EC, 2012): http://europa.eu/rapid/press-release_MEMO-12-787_en.htm

Biograce, Calculator of bioenergy GHG emission reduction, available online at http://www.biograce.net/

Further Reading

CIFOR, 2011. A global analysis of deforestation due to biofuel development

FAO Bioenergy and Food Security (BEFS) website: http://www.fao.org/energy/befs/en/

IEA, 2012. Technology Roadmap – Biofuels for Transport

REN21, Renewables 2015 Global Status Report

QUINVITA, 2014. Regional potential assessment of novel bioenergy crops in fifteen ECOWAS countries

World Resources Institute: WRI, 2015. Avoiding Bioenergy Competition for Food Crops and Land