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SECOND GENERATION BIOFUEL MARKETS:

STATE OF PLAY, TRADE AND DEVELOPING COUNTRY PERSPECTIVES

UNITED NATIONS

Note

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Acronyms

2G	Second-generation biofuels
ABPP	Africa Biogas Partnership Programme
BCAP	Biomass Crop Assistance Program
BETO	Bioenergy Technologies Office
BIP	Biofuel Infrastructure Partnership
BMELV	German Federal Ministry of Food, Agriculture and Consumer Protection
BNDES	Brazilian Development Bank
CNG	Compressed Natural Gas
CTBE	Brazilian Bioethanol Science and Technology Lab
CWC	Cellulosic Biofuel Waiver Credit
DoD	US Department of Defence
DOE	United States Department of Energy
EC	European Commission
EISA	United States Energy Independence and Security Act
EJ	Exajoule
EMTS	US Environmental Protection Agency Moderated Transaction System
EPA	US Environmental Protection Agency
EU	European Union
Fapesp	São Paulo State Research Foundation
Finep	Brazilian Innovation Agency
FTA	Free Trade Agreements
GATT	General Agreement on Trade in Goods
GBEP	Global Bioenergy Partnership
GHG	Greenhouse Gas
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
iLUC	Indirect Land-Use Change
IRENA	International Renewable Energy Agency
ISCC	International Sustainability and Carbon Certification system
ISO	International Organization for Standardization
LCFS	Low Carbon Fuel Standard
LDCs	Least Developed Countries
LIIB	Low Indirect Impact Biofuels
LNG	Liquefied Natural Gas
MFN	Most-favoured nation obligation
MSW	Municipal Solid Waste
NABC	National Advanced Biofuels Consortium
NBP	National Biogas Programme
NREL	United States National Renewable Energy Laboratory
Norad	Norwegian Agency for Development Cooperation
PAISS	Joint Plan for the Industrial Technological Innovation of the Energy and Chemical Sugarcane-based Industries
RDIF	Renewable Drop-In Fuels
RED	Renewable Energy Directive
RFA	Renewable Fuels Association
RFS	Renewable Fuel Standard
RIN	Renewable Identification Numbers
RSB	Roundtable on Sustainable Biomaterials
RVOs	Renewable Volume Obligations
SDGs	Sustainable Development Goals
SIDS	Small Island Developing States
SNG	Synthetic Natural Gas
TBT	Agreement on Technical Barriers to Trade
TRS	Total Recovery Sugars
UCO	Used Cooking Oil
US	United States of America
USDA	United States Department of Agriculture
WTO	World Trade Organization
WWF	World Wide Fund for Nature

EXECUTIVE SUMMARY

UNCTAD's first report on the state of biofuel technologies in 2007 highlighted a sector with great potential, but at the time that was a long way off from markets. In 2015, countries made commitments toward a more environmentally balanced future through the Sustainable Development Goals (SDGs), and now seek to expand policies for low-carbon development after the agreement reached in Paris at COP21. The year also marked a milestone in the bioeconomy, as the point in time when the production of second-generation biofuels (2G) finally took off at commercial scale. Developing countries now face a new set of market opportunities and policy dilemmas to enhance their usage of biomass, which can now be transformed into more valuable products. This report focuses on how these market opportunities can be capitalized on and how to promote technology transfer for developing countries interested in engaging in advanced biofuel markets for the attainment of the SDGs, and as an instrument to meet their commitments under COP21. By carrying out a non-exhaustive mapping of cellulosic ethanol projects and recent policy lessons around the globe, this report seeks to provide public and private practitioners with a macro-picture of the advanced biofuels sector, with a specific focus on cellulosic ethanol as of 2015-2016.

Second-generation biofuels can be classified either by: process type, estimated Greenhouse Gas (GHG) emissions reductions compared to the fossil-fuel equivalent, or feedstock type. This report primarily looks at feedstock choice, which concerns fuels made from non-edible feedstocks, partially in reaction to the food versus fuel debate. Nevertheless, process improvements have been a key factor in decreasing costs for the industry and allowing market expansion. Historically, the United States of America (US) has had the largest installed capacity for cellulosic ethanol production of deployed second-generation biofuel facilities, followed by China, Canada, European Union (EU) and Brazil, respectively. Projects in these countries vary significantly in their technological approaches and feedstocks used for fuel production, including the use of corn stover, sugarcane bagasse, municipal solid waste, and forestry residues, among others. One common trait is that companies that possess technology and knowledge in the EU and the US engage in partnerships to deploy advanced ethanol facilities abroad, for example, the Fuyiang project, which is a cooperation between Italy-based Beta Renewables and Guozhen Group in China. While the African continent and the entire Latin-American region (excluding Brazil) have no cellulosic ethanol projects as of 2015, progress has been made in bagasse-fired electricity cogeneration and biomass cook stoves in these regions.

The policy instrument that has provided the greatest traction to advanced biofuels has been the market-segmentation strategy in conventional / advanced / cellulosic biofuels used in the US market, albeit by granting price premiums for the production of cellulosic ethanol. Low interest rates and a venture capital culture have also been tooted for advancing the deployment of second-generation biofuels in US market forward. Furthermore, the rapid growth of China in the advanced cellulosic ethanol industry, as well as strong support to the sector by the National Development Bank in Brazil, all illustrate the multiple supply and demand pull mechanisms, which have given traction to the industry globally.

While installed capacities have been scaled-up over the past three years, interviews carried out during the preparation of this report suggest that actual production is much smaller than nominal capacities. This could be explained by several factors including feedstock costs, process costs, a lack of domestic regulatory frameworks favourable to advanced biofuels, risk avoidance, and blend walls in major markets. While this report has mapped production capacities, the availability of actual production data is limited as such information is treated confidentially by the industry. In the case of the US, the expected utilization of cellulosic fuels in the market Renewable Volume Obligations (RVOs) for 2015 corresponds to 400 million litres, or about 80 percent of the installed US capacity as of 2015 as surveyed in this report. Based on the limited data available, actual production data in 2014 corresponded to a utilization rate of 25 percent of the US installed capacity for cellulosic fuel. Indicating an optimistic stance, the US Environmental Protection Agency (EPA) has issued obligations that nearly double the cellulosic ethanol requirements for the US market in 2016, calling for imports to meet the likely shortfall in domestic capacity.

Trade opportunities might exist in advanced biofuel markets, particularly as recent limits on conventional biofuels in Europe, together with the EU's growing self-sufficiency in conventional biofuels, suggest that imports of advanced biofuels will most likely be made if domestic producers fail to deliver their expected output. The US is also likely to begin cellulosic ethanol imports in the years ahead, as its own official statistics suggest. Depending on future rules on advanced biofuels in important markets, potential World Trade Organization (WTO) outcomes could be similar to those raised for first-generation biofuels, which led to special sustainability requirements for biomass, and may work as indirect barriers to trade.

The report concludes with five suggestions for the responsible development of the second-generation biofuels industry:

- Create regulatory frameworks for advanced bioenergy tailored to national circumstances, which do not necessarily focus on the type of supply but instead on the existing local demands. The fulfilment of such regulation is most likely to meet domestic development strategies in line with the SDGs.
- Promote cooperation between domestic organizations and foreign companies for joint ventures by means of investment agreements in order to facilitate technology transfer. This is important to avoid the emergence of a large technological gap between first-generation, land-intensive feedstocks and second-generation, capital-intensive biofuels in developed and developing countries.
- Consider the broader aspects of bioeconomy sectors, including biomaterials, in ways that avoid locking industrial development paths into specific sectors or technologies. This would provide flexibility for market players that operate biorefineries as they could target multiple markets, including materials, feed, food, and energy - both domestic and internationally.
- Incorporate lessons from sustainability criteria applied for first-generation biofuels into near and mid-term sustainability provisions or labels for advanced biofuels.
- Continuously promote technical dialogue among different production regions of advanced fuels in order to ensure compatible standards for feedstock and promote trade in advanced biofuels.

Advanced biofuels are an important tool to be considered in national policy in the coming decades. They are a renewable energy option with great potential help decarbonize transportation and other systems in developing countries. Advanced biofuels consequently relate to numerous SDGs and national commitments to limit climate change to tolerable levels. Their responsible development in the coming years should take into account lessons from first-generation biofuels (and other renewable energy technologies), which have received intense scrutiny in recent years. In particular, rules on trade and the sustainability aspects of advanced biofuels should be applied coherently with other regulations, both domestically and internationally.

Photo credits: Henrique Pacini - Usina Pirangueiras; GranBio

1. INTRODUCTION

Since 2006, several developed and developing countries have established blending mandates for biofuels, including sustainability norms for their responsible production. As a follow up to an initial study on the implications for developing countries in the biofuel markets produced by UNCTAD in 2006, substantial interest was raised on the so-called advanced biofuels sector, which held great promise for reducing the social and environmental risks associated with biofuel production and usage (UNCTAD, 2014).

In response, UNCTAD published a second report on biofuel production technologies in 2008, which sought to educate policymakers on the various options that exist when countries opt to pursue biofuel targets for their national energy systems. At the time the report was published, a strong debate on the sustainability of biofuels was taking place around the world, mainly focused on the so-called first-generation (food-based) biofuels.

In 2014, UNCTAD published an update on the state of the global biofuel markets (UNCTAD, 2014).[1] It briefed audiences on the unprecedented increase in public and private sector interest for liquid biofuels between 2006 and 2014. By 2015, liquid biofuels had become commonly traded commodities worldwide. The impetus behind biofuels was partially due to novel drivers such as green jobs and the interest in the de-carbonization of specific sectors of the economy such as transport, but also to provide countries dependent on oil imports with an alternative to enhance their energy security and create new export opportunities.

Biofuel markets underwent significant transformation between 2006 and 2015. Biofuels expanded beyond their traditional usage in the road transport sector, and are now being used on larger scales for aviation, electricity generation, cooking energy, and even maritime transport. Governmental and private strategies in many countries also evolved from a limited scope of liquid biofuels to broader notions of bioenergy (solid, liquid and gaseous energy products), as well as ways to increase the efficiency of biomass utilization for biofuel and biomaterial production by means of biotechnology processes. In what is now known as the bioeconomy, economic systems must consider the usage of biomass not only for energy, but also for food, feed and fibre as additional outputs (Juma and Konde, 2001; Kirscher, 2012).

The emergence of better science around the issue of land use change associated with the production and usage of biofuels cast doubt on the use of first-generation biofuels, made from edible agricultural feedstocks, as a tool to reduce greenhouse gases (GHG) emissions. While many countries sought to enter the international biofuels market, and draw on the latest technology to move away from crop-based biofuels and into cellulosic and algae-based advanced fuels, the list of producing countries has not changed substantially since our first assessment published in 2006 (UNCTAD, 2006). As nations have made progress on the policy front, investments have maintained the trend towards conventional biofuels and therefore, on a limited number of producing areas that offered more predictable business conditions for entrepreneurs.[2]

While great potential remains untapped for the more sustainable production of first-generation biofuels in developing countries, more attention is now given to second-generation biofuels and biomaterials. Such advanced biofuels, which are primarily made of non-edible feedstocks, started to be marketed on a commercial level between 2013 and 2015. They can also increase trade in biofuels by allowing a larger trade of feedstocks such as cellulosic and waste material, combined with practices adopted in the pellets and pulp & paper industries.

With a considerable increase in biofuels trade since 2006, sustainability certification gradually became a new norm in the industry, and a de-facto prerequisite for market access. After an intense debate on the formulation of sustainability regulations, certification, and labeling of biofuels and feedstocks, sustainability criteria for biofuels has evolved mainly through voluntary schemes compliant with legislation adopted in major markets, such the United States of America (US) and the European Union (EU).

While most countries discussed the pros and cons of biofuels, two approaches to sustainability in this area emerged during the period 2006-2015. One approach was to improve the current-generation biofuels. The second was to promote technological improvements that allowed for a broader scope of biomass to be processed into energy and biomaterials, reduce competition for food crops, which traditionally served as the main feedstock for biofuel production (Scarlat and Dallemand, 2011; Pacini and Strapasson, 2012). In other words, initiatives were launched to make conventional biofuels better, as well as promote supply-side innovation, which carried fewer potential negative externalities (Lora et al, 2011). This report explores the current state of second-generation biofuel markets, their potential contribution to the Sustainable Development Goals (SDGs) and selected regulatory frameworks, as well as implications that are likely to arise for Developing Countries and for international trade in biofuels from the perspective of World Trade Organization (WTO) law.

1.1 Definitions

In its 2008 report, UNCTAD defined the key difference between first and second-generation biofuels based on their feedstock characteristics. As illustrated in Table 1, first-generation biofuels are derived from seeds, grain or sugars, while second-generation biofuels are produced from lignocellulosic biomass, such as crop residues, woody crops or energy grasses (UNCTAD, 2008). This definition will be used throughout this report.

While many of the technical processes for the conversion of non-food biomass into biofuels were already feasible in the mid-2000s, no significant quantities of advanced biofuels existed in the market in 2008 (Hamelinck and Faaij, 2006; UNCTAD, 2008). After 2013, this scenario began to change. What was once a very theoretical policy debate concerning second-generation fuels now became a reality as cellulosic and waste-based fuels started to be produced on a commercial scale.

While a recent study from UNCTAD (2014) provided an update of the state of international biofuel markets[3], this report focuses on market deployment levels and the policy aspects of advanced biofuel markets, and cellulosic ethanol in particular. The rationale behind this report is the common interest countries share to both better understand the technological and policy options available to improve energy security, and promote cleaner transport and competitiveness concerns in emerging industries that form the bioeconomy (Jordan et al., 2007).

Starch, sugar, palm and grain-based bioethanol and biodiesel continue to be the primary driver of international biofuel markets. As of 2015, markets in developing and developed countries, particularly the US, the EU, China, Canada and Brazil have proven to be dynamic and at the forefront of the deployment of advanced biofuels worldwide. These countries and regions are also responsible for the majority of world trade in biofuels.

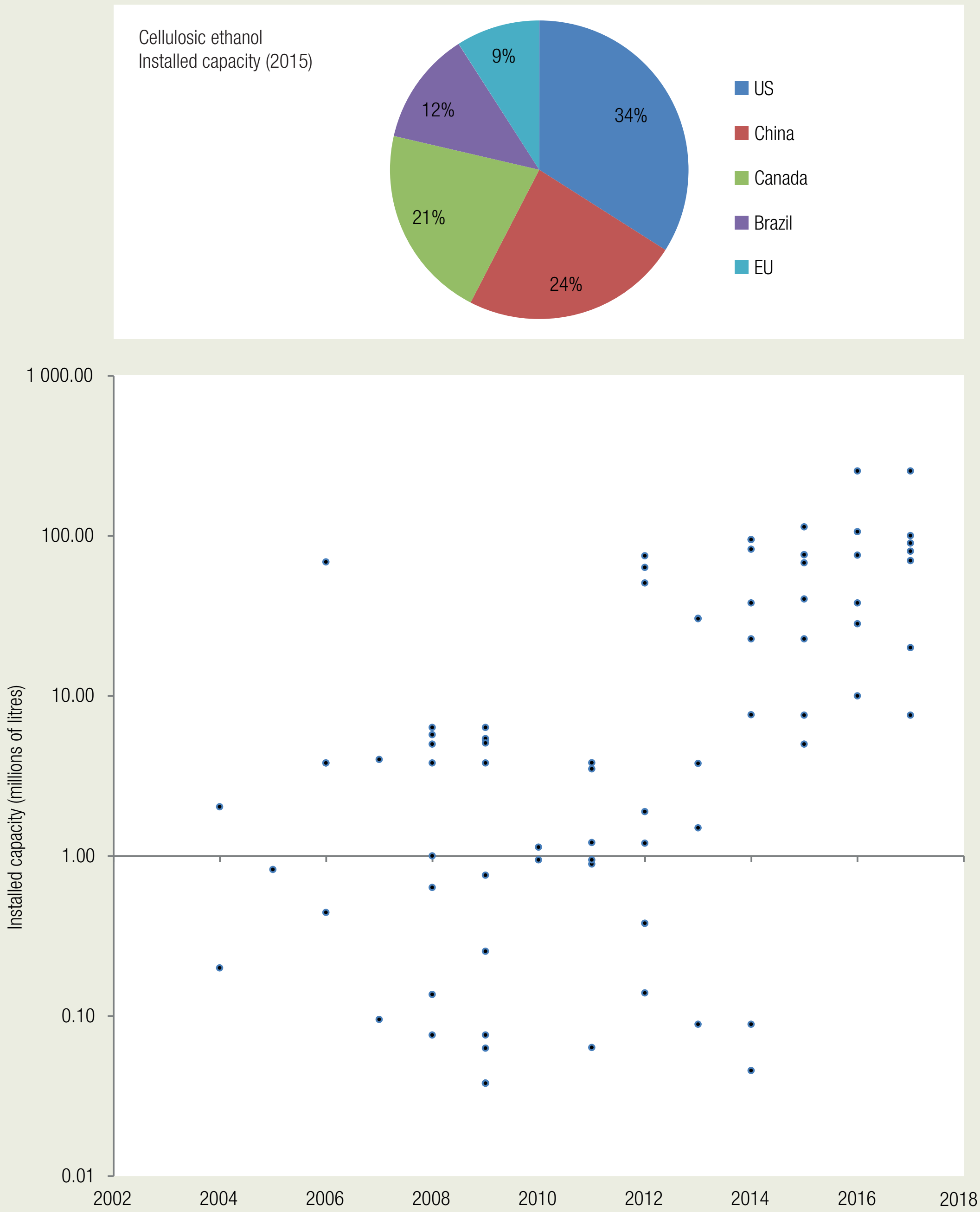
At the time this report was written, there was limited international trade in bioethanol feedstocks, partially due to the non-tradable and perishable characteristics of some feedstocks (e.g. sugarcane), and to the dual role that some countries have as both producers of feedstock and consumers of biofuels (e.g. cereals-ethanol, sunflower-biodiesel in the US and in the EU). Biodiesel production outside of the EU has grown since 2006, but most EU imports are still derived from vegetable oil, from countries such as Malaysia, Indonesia and Argentina. The second-generation biofuels, which are primarily made from non-edible

Table 1: Different generations of biofuels

First-generation biofuels (from seeds, grains or sugars)	**Second-generation biofuels** (from lignocellulosic biomass, such as crop residues, woody crops or energy grasses)
• Petroleum-gasoline substitutes ◊ Ethanol or butanol by fermentation of starches or sugars • Petroleum-diesel substitutes ◊ Biodiesel by transesterification of plant oils (FAME and FAEE) » Can be produced from various crops such as rapeseed (RME), soybeans (SME), sunflowers, coconut oil, palm oil, jathropha, recycled cooking oil and animal fats ◊ Pure plant oils (straight vegetable oil)	• Biochemically produced petroleum-gasoline substitutes ◊ Ethanol or butanol by enzymatic hydrolysis • Thermochemically produced petroleum-gasoline substitutes ◊ Methanol ◊ Fischer-Tropsch gasoline ◊ Mixed alcohols • Thermochemically produced petroleum-diesel substitutes ◊ Fischer-Tropsch diesel ◊ Dimethyl ether (substitutes propane as well) ◊ Green diesel

Source: UNCTAD (2008).

Figure 1: Second-generation ethanol plants (entire world) per start date of operations and production capacity (data as of 2015)



Source: Ethanol Producer Magazine, IEA task 39 and European Biofuels Technology Platform.

feedstock and started to be marketed at a commercial level in 2013, are likely to change this situation by allowing greater trade in feedstocks, such as cellulosic, woody and waste material. This new trade regime will likely be driven by practices adopted in the pellets and pulp & paper industries. This represents an opportunity for numerous countries to participate in the emerging second-generation (2G) biofuels industry.

With the adoption by UN member-states of the SDGs in September 2015, the linkages between energy and development will be high on international agendas until 2030. The specific SDG 7, which deals with Sustainable Energy, calls for universal access to modern energy services, a substantial increase in the share of renewable energy in the global energy mix, as well as gains in energy efficiency.[4] SDG 7 actually includes point 7a and point 7b, which calls for greater international cooperation to facilitate access to clean energy research and technology, including the upgrade of energy services and supply infrastructure particularly in the Least Developed Countries (LDCs) and Small Island Developing States (SIDS).

Therefore, energy will be a fundamental part of developing country strategies to meet these specific goals set out by the SDGs, including their actions geared towards tackling climate change in accordance with COP21 and creating new sources of employment compatible with low-carbon development strategies.

2. FIRST-GENERATION BIOFUELS: THE STATE OF PLAY

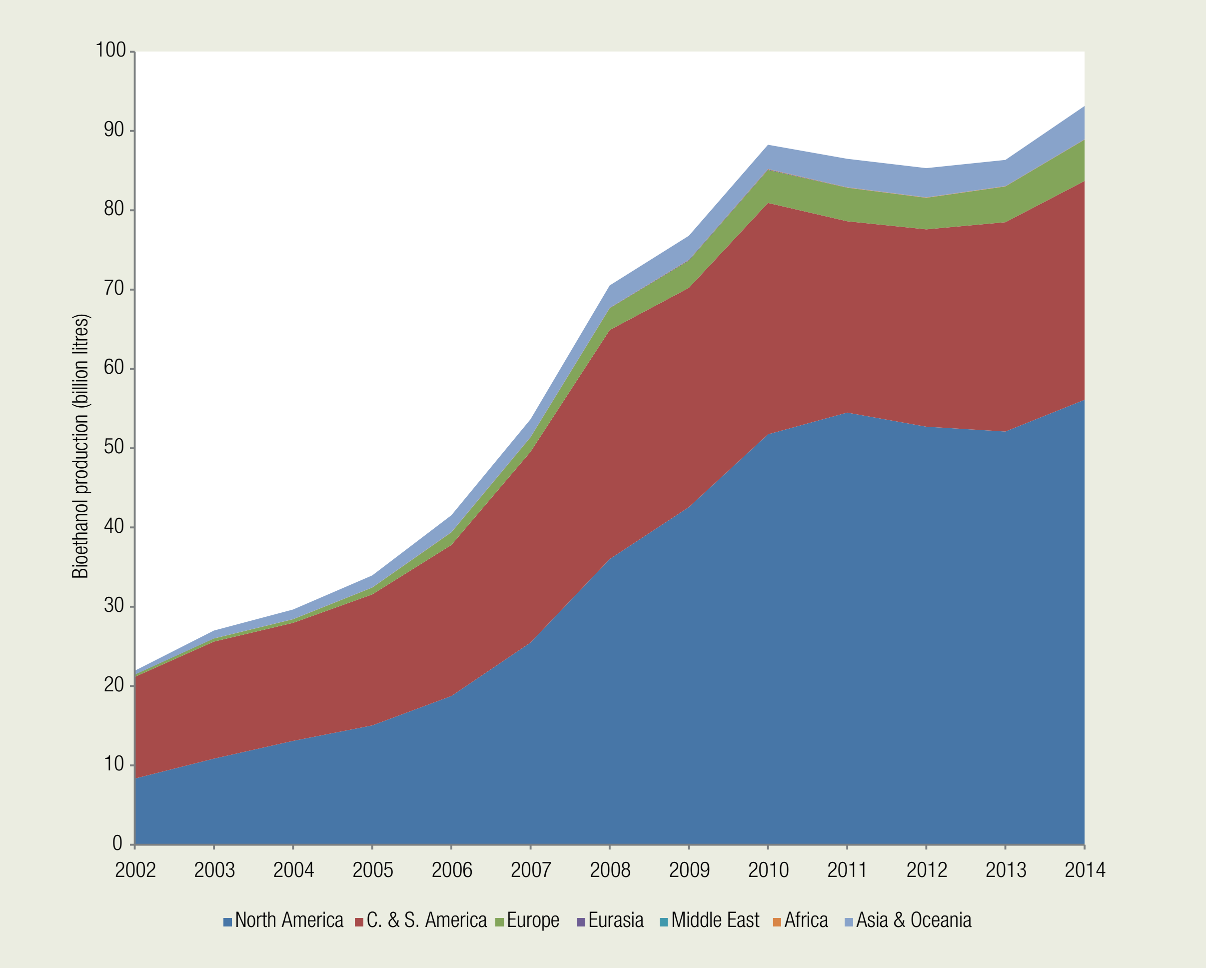
Food crops such as starch, sugar and vegetable oil, as well as animal fats, are the main feedstock sources to first-generation biofuels (UNCTAD, 2014). These types of feedstock characterize first-generation biofuels, which are defined based on the source the fuel is derived rather than the physical nature of the biofuel itself.

The most popular first-generation biofuels are biodiesel (produced mainly from canola, soybean and barley) and bioethanol (produced mainly from corn, wheat and sugarcane) followed by other types of vegetable oil and biogas. Figures 2 and 3 show that global biofuel production grew steadily from about 23 billion litres per year in 2002 to over 110 billion litres per year in 2012. Growth rates in this market decreased between 2011 and 2012, and the annual production of biofuels in 2015 was roughly equal to 2010 levels.

Led by Brazil and the US, ethanol production more than doubled since 2005, reaching 85.6 billion litres in 2010 and 94 billion litres in 2014 (REN21, 2014), and biodiesel production grew from 3.9 billion litres in 2005 to 18.1 billion litres in 2010 and 30 billion litres in 2014 (REN21, 2014).

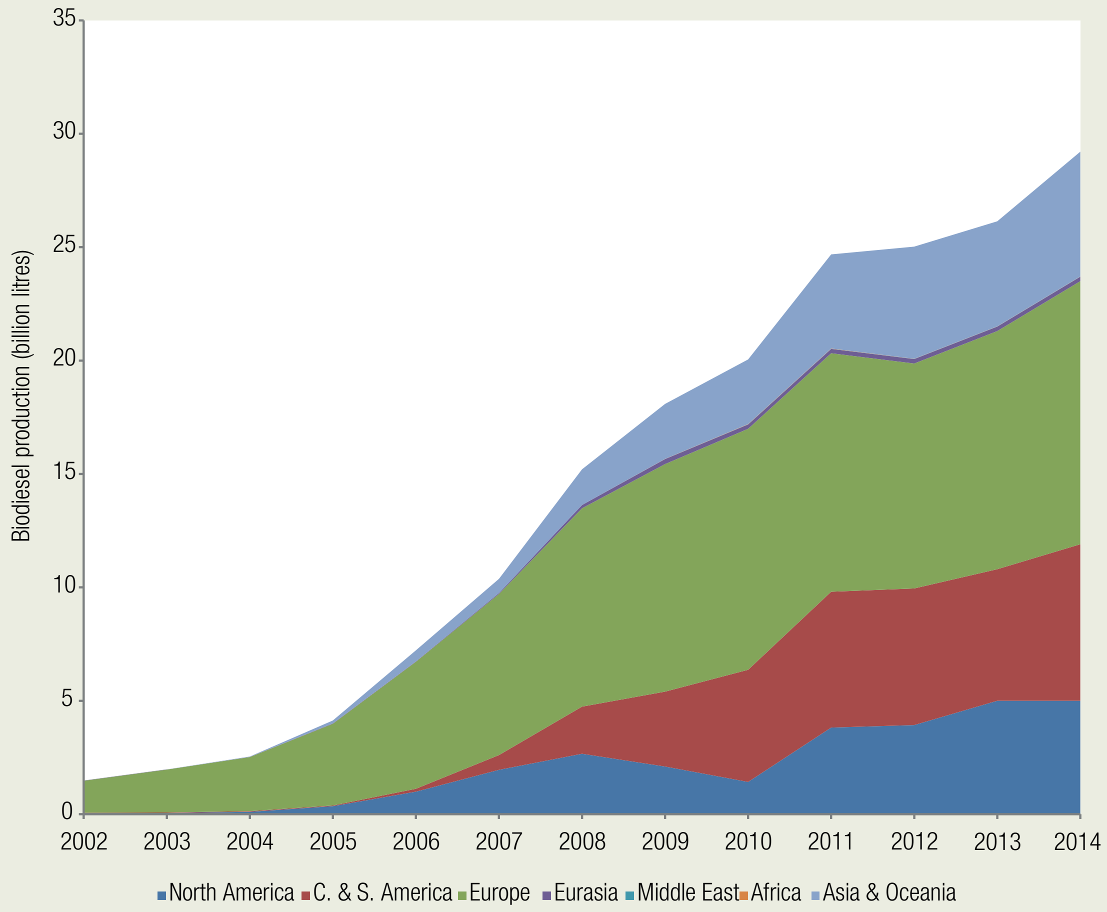
The Americas produce more than 80 percent of the global biodiesel and bioethanol production. Ethanol production actually has two major players, namely the US and Brazil, which cumulatively account for 73 percent of the global production. Both countries have a history of government support for their biofuel

Figure 2: World bioethanol production, per world region



Source: EIA (2015)

Figure 3: World biodiesel production, per world region



Source: EIA (2015).

Box 1: Case example - Solena fuels

Solena's Integrated Biomass-Gas to Liquid "IBGTL" solution is based on a Fischer-Tropsch platform to produce sustainable fuels from low carbon-bearing organic waste.

The IBGTL process can handle a wide variety of feedstock and thus is "fuel flexible". In 2010, British Airways announced its GreenSky London project, in which London will transform tons of municipal waste – normally sent to landfills – into Bio-SPK, Green Fisher Tropsch Diesel and Green Fisher Tropsch Naphtha. Approximately 575,000 tons of post-recycled waste, normally destined for landfill or incineration, will instead be converted into 120,000 tons of renewable liquid fuels. British Airways has made a long-term commitment to purchase all 50,000 tons per annum of the jet fuel produced at market competitive rates.

In November 2013, Solena Fuels began discussions with city authorities in Chennai, India, to use the city's daily 5,000 tons of municipal solid waste to annually produce 120 million litres of aviation biofuel and 45 million litres of diesel. The facility would cost US$ 450 million to build with an eight-year return on investment.

Source: Adapted from Biofuels Digest (2015).

Table 2: Characteristics and costs of conventional biofuels

Biofuel type	Feedstocks	Feedstock characteristics	Estimated production costs US$ cents/litre
Biodiesel	Soy, rapeseed, mustard seed, palm, jatropha, waste vegetable oils and animal fats.	Range of feedstocks with different crop yields per hectare; hence, production costs vary widely among countries. Co-products include high-protein meal.	Soybean oil: 56–72 (Argentina); 100–120 (Global average). Palm oil: 100–130 (Indonesia, Malaysia, and other). Rapeseed oil: 105–130 (EU).
Ethanol	Sugar cane, sugar beets, corn, cassava, sorghum and wheat.	Range of feedstocks with wide yield and cost variations. Co-products include animal feed, heat and power from bagasse residues. Advanced biofuels are starting to become fully commercial and still have higher production costs.	Sugar cane: 82–93 (Brazil). Corn (dry mill): 85–128 (US).

Source: REN21 (2015).

industries, in the same way that the EU has for its biodiesel industry, which is the largest in the world with 40 percent of global production.

There are many factors, which simultaneously constrain and strengthen the growth of the global biofuels market. These include potential negative impacts on food commodities, the availability of natural resources, government subsidies, national commitments to mitigate climate change, oil prices and other political/environmental factors. Biofuel production faces different challenges around the world. Africa suffers from overestimated expectations and agricultural difficulties with some feedstocks, such as Jathropha, but despite these challenges, countries such as Mali, Ghana and Nigeria have established mandates for the use of biofuels. India is working on a biofuel target of 10 percent and the government has created incentives to production in the form of capital subsidies, tax breaks and public bidding processes. In Latin America, fuel demand is rising and fossil-fuel subsidies are being slowly phased out, at the same time novel biofuel models are being developed, since the Brazilian experience is not replicable in many of its neighbours with smaller land availability.

Biofuels have a potential to overcome environmental challenges by reducing dependence on fossil fuels. Economically, biofuels sustain more than 1.7 million jobs around the world, including 845,000 in Brazil and 282,000 in the US (REN21, 2015). However, it is important to note that the emergence of a technological gap between land-intensive first-generation and capital-intensive second-generation biofuels can compromise the catch-up strategies implicit on the investments made by the poorer countries.

3. FIRST-GENERATION BIOFUELS: SUSTAINABILITY ISSUES

Several sustainability issues surround the increasing demand for first-generation biofuels and biomaterials. One is the increasing pressure to make land-use changes in favour of biomass feedstock production. This can be a challenge in two ways:

- Direct land-use change – for example, by removing forests to make way for agricultural production. This issue can be managed by utilizing a standard that requires production to take place on land that has not been converted when compared to a reference year.
- Indirect Land-Use Change (iLUC) – typically caused by supply and demand. This issue can be addressed by defining how additional biomaterials can be produced without affecting land use.

Some certification schemes, such as the the Roundtable on Sustainable Biomaterials (RSB)[5], have been working to show how some biofuels and biomaterials have a much lower risk of generating iLUC. A number of criteria can be defined to specify practices that reduce the risk of iLUC as opposed to quantifying iLUC as has been pursued at the mainstream biofuel policy regulations in the EU and the US. Compliance with low-iLUC practices can help producers demonstrate that biomass was produced with no indirect impact on food production or biodiversity. The RSB Standard, for example, includes measures to mitigate food insecurity in parts of the world with food poverty, and add-on standards to promote practices that allow biomass for biofuels and biomaterials to be grown with minimal impact on food production.

3.1 Three low iLUC approaches

The RSB criteria and compliance indicators provide an interesting example of how iLUC risks can be reduced. Their criteria define a series of requirements to reduce iLUC, by determining whether market operators fit into one of the three proposed categories. The criteria and indicators are based on the Low Indirect Impact Biofuels (LIIB) Methodology[6], which was developed by a partnership between RSB, the World Wide Fund for Nature (WWF) and Ecofys. The three different approaches are described below.

Yield increase:

The Yield Increase approach applies to any situation where feedstock producers are able to increase the amount of harvested biomass from a fixed area of land. An increase in the harvested biomass may be the result of:

- An improvement in agricultural practices, e.g. fertilisation, crop protection, improved crop varieties, precision farming.
- Intercropping, i.e. the combination of two or more crops that grow simultaneously, for example as hedges or through an agroforestry system.
- Crop rotation, i.e. the combination of two or more crops that grow at different periods of the year.

RSB also stresses the importance for producers to develop a management plan in which yield increase measures are documented, together with their expected contribution to increased yields and evidence of their implementation.

Yield increases are established with respect to a reference year, which can be 2008 or the year preceding the implementation of yield increase measures, whichever is later. The 'baseline scenario yield' and 'reference yield' are then established. The reference yield is the average yield of the producer over the preceding five years, which is multiplied by either the average annual yield growth for similar producers in the region, or set to a default value of 1.1, to obtain the baseline scenario yield. The actual amount of low iLUC risk biomass is calculated by the difference between the actual yield and the baseline scenario yield multiplied by the land under cultivation with the specific crops to which yield increase measures have been applied. Specific equations to use are detailed in the actual document.

In cases where a food crop is combined with an energy crop, operators should monitor that the increase in biomass harvested from the energy crop does not come at the expense of the harvested biomass from the food crop, even if the total harvested biomass (i.e. food crop + energy crop) increases.

Unused/degraded

Land: Producers need to demonstrate that the land was not used for 'provisioning services' during the three years preceding the reference date, which is 1st of January 2008, or the date when the unused land was put in cultivation, whichever is later. The definition of provisioning services comes from The Millennium Ecosystem Assessment 2005[7], which covers food, animal feed and bioenergy feedstocks. In addition, no shifting cultivation or prolonged crop rotation systems, in which fields are left fallow for up to ten years, shall take place on the land.

An intermediate case can apply when the land has been previously used in a limited way. More specifically, the land was used for provisioning level up to a yield that is 25 percent or less (by energy content, protein content or estimated market price) of the earnings or yield that can be reasonably expected from cultivation of the same crop(s) in normal conditions. In this case, the producer must demonstrate that the yield obtained through the limited provisioning services that existed prior to the reference date did not decrease due to the new operations. If the new operations do affect these limited provisioning services, the producers must provide compensation providing equivalent benefits to local communities in line with specific RSB Principles and Criteria. In this case, only the biomass produced in addition to the biomass obtained from existing provisioning services is eligible as low iLUC risk biomass.

Use of waste/residues:

In the EU, wastes and residues are classified as such by both the EU Renewable Energy Directive and individual Member States. Examples include used cooking oil (UCO), municipal solid waste (MSW), agricultural residues (e.g. straw), wastewater, and animal fats that are unsuitable for food or feed. However the material must satisfy additional criteria for it to be low iLUC risk. It should be generally discarded for landfilling or incineration in the region where it is generated, with no other use planned for it. A region can be at the sub-national (e.g. a metropolitan area, a state or a province), national, or supra-national (e.g. several countries, EU, the Economic Community of West African States region) level. A larger region involves a greater availability of feedstock, but a smaller region makes it easier to demonstrate that no other uses are currently being made of a given waste/residue. Alternatively, an operator can demonstrate that the use of the waste/residue does not result in an indirect increase in greenhouse gas emissions by proving that fossil fuels are not required and that the material was not previously used as food, feed or fibre.

3.2 Supporting rural development and smallholders

Economic development opportunities often by-pass small agricultural producers because of a lack of capacity, economies of scale, and access to technology. While global markets are expanding, sustainability certification standards are often required to access these markets, which is typically beyond the reach of small-scale farmers due to the costs involved. Smallholders sometimes use inappropriate production practices that are detrimental to forests, soils, and water supplies and the prospects for maintaining production levels over time.

In addition to improving agriculture or feedstock production practices and environmental impacts among smallholders, sustainability standards can help ensure that first-generation feedstocks promote rural development. With the tremendous growth in biofuels in India, Malaysia, Indonesia and other countries, there is a huge need for sustainability standards to safeguard rural development. This may include supporting local communities, providing jobs, ensuring human rights protection, improving air and water quality, and deforestation protection.

Biofuel projects should be designed to have minimum impact on existing food production areas. For example, by setting aside large areas of land in the project area for community use or establishing a farmer or smallholder development training program can help local communities thrive while also improving food security through better adapted farming methods. Feedstocks that have multiple uses and end products, and that can support soil fertility, can also be very beneficial to smallholders.

For example, with the support of Boeing and the Swiss State Secretariat for Economic Affairs, the RSB is conducting a program to understand and address the challenges for smallholder farmers in accessing markets for sustainable biofuels and biomaterials. RSB developed a specific smallholder standard to consider the context and challenges faced by smallholders to achieve sustainable practices, whilst providing guidance for improvements. This results in opportunities for family farmers by creating social and environmental benefits with additional income.

Experiences from Malaysia, India and the Philippines suggest that with adequate technical and financial support, biofuels feedstock cultivation and processing can be successfully incorporated into traditional farming systems, while providing complementary sources of income and enhancing local uptake of modern energy and materials. After starting in Southeast Asia and Mexico with the assistance of the Norwegian Agency for Development Cooperation (Norad), the RSB project has been expanded to Brazil and Southern Africa, with an assessment of local biomass and biofuel production and selection of pilot projects.

The relatively high cost typically puts certification out of reach for disadvantaged producers, so the RSB smallholder project looks for innovative ways to overcome this hurdle and increase their access to sustainability certification. One example is RSB's global standard for smallholder groups, and their work to understand how to make it easier for smallholders to become certified, as well as how its regional members can support uptake of the standard. Certification opens up new markets for smallholder-produced feedstocks. RSB also works with private sector partners to identify buyers for smallholder production, thus providing market access and developing sustainable supply chains. Such initiatives allow smallholder and rural development organizations to gain an understanding of distribution channels, and identify relevant players and their specific functions in the development of the industry in the target countries.

3.3 Criteria and sustainability standards

Several efforts are under way to develop sustainability criteria and standards that aim to provide assurance on the overall sustainability of biofuels, including for trade purposes. These include efforts to co-ordinate activities at the global level, as well as national and regional initiatives (OECD/IEA, 2011). International initiatives include:

- The Global Bioenergy Partnership (GBEP) - an intergovernmental initiative with partners from 23 member countries and 14 international organizations (along with 39 Observers) aiming to foster sustainable bioenergy production and use. Among other things, GBEP has produced a set of 24 indicators for the assessment and monitoring of bioenergy sustainability at national level. These indicators have already been implemented in a number of countries. In addition, GBEP has developed a Common Methodological Framework for the GHG Lifecycle Analysis of Bioenergy.
- The Roundtable on Sustainable Biomaterials (RSB) - an independent and global multi-stakeholder coalition, which works to ensure the sustainability of biofuels and biomaterials. RSB's certification scheme is known for its stringency and verifies that biomaterials are ethical, sustainable and credibly sourced. The certification is approved by RSB's members across several sectors, including leading NGOs and UN agencies.
- The International Organization for Standardization (ISO) - responsible for the international standard via a ISO project committee (ISO/PC 248, Sustainability Criteria for Bioenergy). The project gathers international expertise and best practice, and identifies criteria that can avoid bioenergy leading to environmental damage or negative social impacts. In addition, the standard aims to make bioenergy more competitive, to the benefit of both national and international markets.
- The International Sustainability and Carbon Certification system (ISCC) - developed the first internationally recognized certification system for biomass. The ISCC certifies the sustainability and GHG savings of all kinds of biomass, including feedstocks for bioenergy and biofuel production.

4. BUILDING MARKETS FOR BIOFUELS

Biofuels can be promoted through a combination of regulatory measures and fiscal incentives, such as biofuel production subsidies, competitive tendering, biofuel blending mandates, tax incentives and exemptions, grants, direct subsidies and others. These measures can be applied at different stages of the production and consumption chain. Some countries for example provide fiscal incentives for flex-fuel vehicles, which can run on different blends of gasoline and bioethanol, while others provide tax credits on biofuels and may allow eligible biofuel production plants to be declared tax-free zones.

As an incentive to the use of renewable energy, one of the most common policies used in the transportation sector is biofuel blending mandating. In 2014, mandates are in place in 42 countries. Within these policy frameworks, various jurisdictions mandate specified bioethanol blends, and 27 mandate biodiesel blends, with many countries enacting mandates for both fuels (REN21, 2015; Biofuels Digest, 2016) (Table 3).

4.1 Feedstock issues

In a broad sense, there are several sources of biomass potentially available for the production of biofuels, such as Dedicated Crops (sugar crops, starch crops, oil crops, lignocellulose crops and algae and aquatic

Table 3: Global biofuel blend mandates

Country	Mandate
Angola	E10
Argentina	E10 and B10
Australia	State: E6 and B2 in New South Wales; E5 in Queensland
Belgium	E4 and B4
Brazil	E27.5 and B7
Canada	"National: E5 and B2 Provincial: E5 and B2 in Alberta, E5 and B4 in British Columbia, E8.5 and B2 in Manitoba; E5 and B3 in Ontario; E7.5 and B2 in Sashkatchewan"
China	E10 in nine provinces
Colombia	E8
Costa Rica	E7 and B20
Ecuador	B5
Ethiopia	E10
Guatemala	E5
India	E5
Indonesia	E3 and B5
Italy	0.6% advanced biofuels blend by 2018; 1% by 2022
Jamaica	E10
Malaysia	B5
Mozambique	E10 in 2012-2015; E15 in 2016-2020; E20 from 2021
Norway	B3.5
Panama	E7; E10 by April 2016
Paraguay	E25 and B1
Peru	E7.8 and B2
Philippines	E10 and B5
South Africa	E5
South Korea	B2.5; B3 by 2018

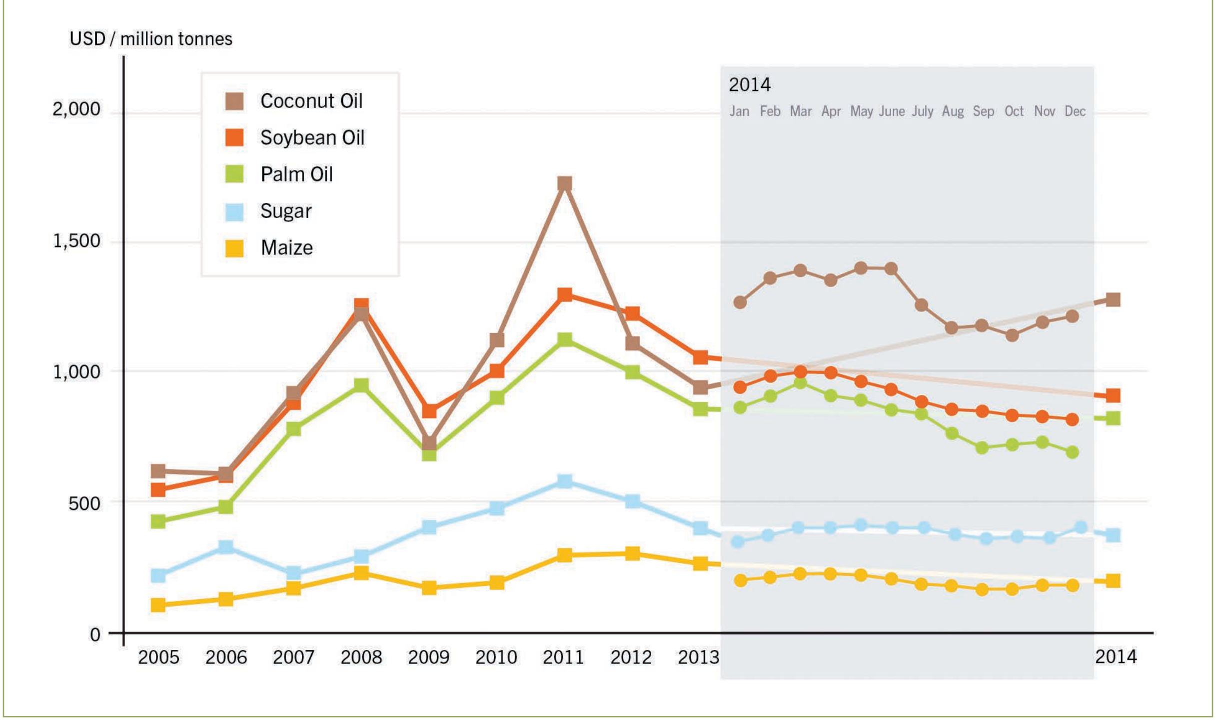
Country	Mandate
Sudan	E5
Thailand	E5 and B5
Turkey	E2
Ukraine	E5; E7 by 2017
United States	"National: The Renewable Fuels Standard 2 (RFS2) requires 136 billion litres (36 billion gallons) of renewable fuel to be blended annually with transport fuel by 2020. The RFS for 2013 was reduced 49.21 billion litres (13 billion gallons). State: E10 in Hawaii; E2 and B2 in Louisiana; B5 in Massachusetts; E20 and B10 in Minnesota; E10 in Missouri and Montana; B5 in New Mexico; E10 and B5 in Oregon; B2 one year after 200 million gallons and B20 one year after 400 million gallons in Pennsylvania; E2 and B2, increasing to B5 180 days after in-state feedstock, and oil-seed crushing capacity can meet 3% requirement in Washington. "
Uruguay	E5 and B5
Vietnam	E5
Zimbabwe	E5, to be raised to E10 and E15 (no date given)

Source: REN21 (2015) and Biofuels Digest (2016).

biomass) and Wastes and Residues (oil-based residues, lignocellulose residues, organic residues and waste gases).

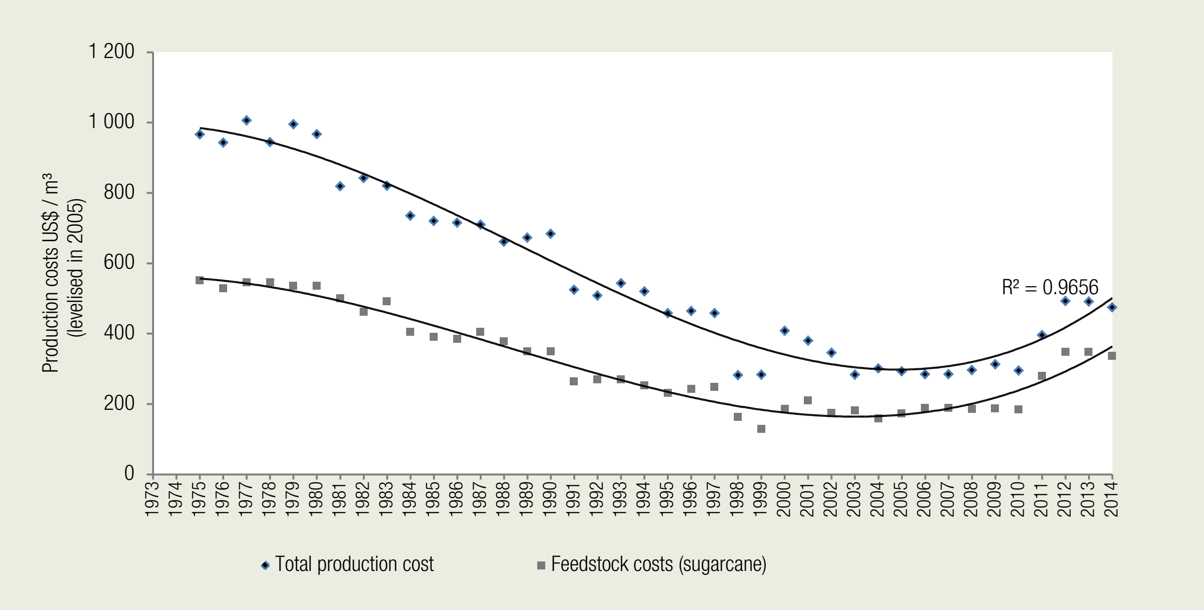
Feedstock generally accounts for around 70 percent of production costs, with processing, transportation, and other costs making up the remainder. Feedstock type varies significantly depending on the country or region. For example, fuel ethanol production in the US is based largely on corn, whereas Brazil relies primarily on sugar crops, and China on sweet sorghum, cassava, and other non-grain crops. In the US during 2014, corn production surpassed 378 million tonnes (14 billion bushels) for the first time,

Figure 4: Global biofuel feedstock prices, 2005–2014



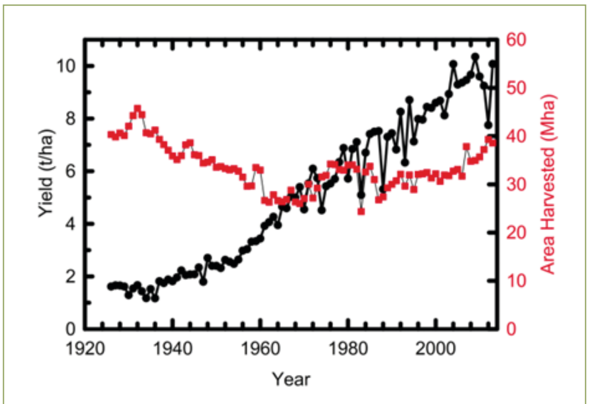
Source: REN21 (2015).

Figure 5: Ethanol production costs in Brazil (1975 to 2014)



Source: Prepared by UNCTAD based on Van den Wall Bake (2009), CNA, PECEGE /ESALQ and Pacini and Strapasson (2012).

Figure 6: Historical progression of maize grain yields per unit land area in the US and the area of the country committed to the crop



Source: Long et al. (2013).

which helped to further bolster US ethanol production. In Brazil, sugarcane harvests recovered somewhat from a drought-induced drop in production in 2013, rising by roughly 3 percent in 2014. Global biodiesel production is based largely on vegetable oils, mostly from rapeseed (Europe) and soybeans (US, Brazil, Argentina), with smaller shares from palm (Indonesia) and other sources such as jatropha and coconut (REN21, 2015).

According to REN21 (2015) the global prices of most key biofuel feedstocks declined in 2014 (Figure 4). This was primarily due to a fall in 2013 feedstock prices including corn (down 26 percent), soybean oil (-14 percent), palm oil (-4 percent), and sugar (-4 percent); the exception was coconut oil. Therefore, declining feedstock prices helped the industry by reducing overall production costs.

In this context the estimated costs for first-generation biofuel production can vary widely. Estimates show that the cost in US$ cents per litre of biodiesel produced from different feedstocks[8] varies as follows: soybean oil: 56–72 (Argentina); 100–120 (Global average); palm oil: 100–130 (Indonesia, Malaysia, and other); rapeseed oil: 105–130 (EU) For ethanol production: sugar cane: 82–93 (Brazil); corn - dry mill: 85–128 (US) (REN21, 2015).

As an example of the progress achieved during the almost 40 years of fuel ethanol in Brazil, the cost of ethanol production has fallen over recent decades, as illustrated in Figure 5. This decrease has significantly contributed to the competitiveness of ethanol compared with gasoline on tank stations in the country (Huse and Salvo, 2013).

The bulk of these biofuels were primarily sourced from two countries, the US and Brazil, and from two crops, maize and sugarcane respectively. The US

Table 4: Biofuel type and production capacity (millions of litres per year)

Fuel	2009	2010	2011	2012	2013	2014	2015	2016
Advanced Ethanol	27.71	42.36	46.52	922.62	2 522.22	4 770.26	8 538.41	8 848.82
Biobutanol	0.08	0.08	0.11	0.11	0.15	586.89	586.89	586.89
BioDME	0.00	0.00	2.20	2.20	115.76	115.76	115.76	115.76
Advanced Biodiesel	0.19	0.19	1.85	9.46	20.78	20.78	20.78	20.78
Bio oil	0.04	3.86	3.90	3.90	3.90	3.90	3.90	3.90
Renewable diesel	412.61	1 540.66	2 449.43	2 968.03	2 968.03	3 043.74	3 111.87	3 111.87
Renewable oils	0.42	0.53	1.51	62.61	201.42	239.28	239.28	239.28
Cellulosic Sugars	0.00	0.04	0.08	0.08	3.82	3.82	102.21	102.21
Renewable Chemicals	124.99	125.45	199.11	209.56	585.64	952.30	1 893.73	1 893.69

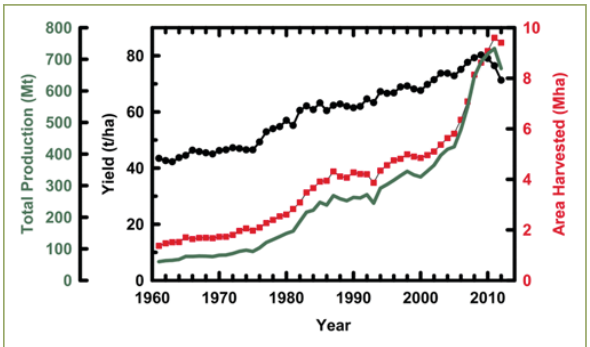
Source: Biofuels Digest, 2011.
Note: 2012-2016 data represents 2011 estimates.
* Renewable Drop-In Fuel.

is the largest producer of first-generation ethanol in the world. In the last few decades, maize in the US has seen a larger increase in yield per hectare than any other major crop (Long and Ort, 2010; FAOSTAT, 2013; USDA-NASS, 2013; Figure 6).

Sugarcane is a major crop grown in the tropical and subtropical regions of the world. Brazil is the main producer of sugarcane in the world. Brazil's sugarcane production has increased more than 10-fold in the last 50 years and doubled in the last 10 years (FAOSTAT, 2013, Figure 7).

In general, biofuels are recognized globally as a crucial element of future transportation and the development

Figure 7: Historical progression of sugarcane yields per hectare, total area harvested and total production in Brazil



Source: Long et al. (2013).

of second-generation production of biofuels provide an important opportunity to meet further growth in the demand for more sustainable transport fuels.

The constraints related to the availability of additional land suggest that second-generation biofuel industries should focus on currently available feedstock sources in the initial phase of the industry's development. Agricultural and forestry residues form a readily available source of biomass and can provide feedstock from current harvesting activities without the need for additional land cultivation (IEA, 2010).

The Advanced Biofuels & Chemicals Project Database, monitored the capacity of advanced biofuels and renewable chemicals for the 2011-2016 period. Project data includes the project developer, proposed capacity, date of completion, fuel type, processing technology, RFS2 category and feedstock in 27 countries that represent the largest share of global production (Table 4). Interestingly, the forecasts presented by the leading industry magazine turned out to be overly optimistic, as updated data presented in this study will show.

There are many projects around the world focusing on the utilization of residues for the production of biofuels. In Thailand, Phuket's Provincial Administration Organization is seeking US$ 22.6 million to build a waste-to-biofuel facility that would use the entire island's municipal solid waste as feedstock. Funding for the project will be sought from the national Ministry of Natural Resources and Environment (Biofuels Digest, 2015). In Canada, Iris Solutions, Plenary Harvest Surrey and Urbaser S.A. have been shortlisted from an original group of 11 companies to invest in, build and operate the city of Surrey's CA$ 60 million residential kitchen and yard waste into a renewable fuel project. The fuel is destined to power the city's garbage collection vehicles (Biofuels Digest, 2015).

Another sector that has seen substantial attention is Waste Cooking Oils (WCO) and animal fats. The collection of used or unrecoverable products for recycling has been growing in recent years mainly due to the increase of societal awareness of environmental issues (Ramos et al. 2013). An example of this is the collection of cooking oil residues that can cause negative environmental impact when incorrectly disposed of. Furthermore, WCO can be used to produce useful products such as biodiesel (Phan and Phan, 2008).

WCO has been a major feedstock for the biodiesel industry in South Korea. However, it is still necessary for the government to encourage the collection of WCO from houses because the supply is limited (Cho et al., 2015). Nevertheless, the price of WCOs is 2–3 times cheaper than virgin vegetable oils (Phan and Phan, 2008). Increasing food consumption has increased the production of a large amount of waste cooking oils/fats. Collected WCO, for example, has been estimated at 4.5–11.3 million litres a year in the

Table 5: Amounts of biofuel and bioenergy that could be produced per unit land area

Common and latin binomial name (region of measurement)	Total dry biomass yield (t/ha)	Grain/ seed/ sugar yield (t/ha)	Easily accessed biofuel (GJ/ha)	Cellulosic (GJ/ha)	Combustion of residue (GJ/ha)	Sum of previous three columns
Maize *Zea mays* (USA)	18.4	9.2	72.8a	40.4	27.6	140.8
Wheat *Triticum aestivum* (EU28)	8.8	5.3	34.9a	19.4	13.2	67.6
Rapeseed *Brassica napus* (EU28)	5.6	2.8	33.2b	12.3	8.4	53.9
Soybean *Glycine max* (USA)	4.7	2.8	21.2b	20.5	5.6	47.3
Sugarcane *Saccharum officinarum* (Brazil)	38.0	12.0	156.8a	167.0	113.9	437.7
Napier grass *Pennisetum purpureum* (El Salvador)	84.0	0.0	0.0	738.2	503.5	1241.7
Miscanthus *Miscanthus x giganteus* (Illinois)	22.0	0.0	0.0	193.3	131.9	325.2
Switchgrass *Panicum virgatum* (Illinois)	10.0	0.0	0.0	87.9	59.9	147.8
Reed canary grass *Phalaris arundinaceae* (Denmark)	12.0	0.0	0.0	105.4	71.9	177.3
Mixed grass prairie (Minnesota)	3.7	0.0	0.0	32.5	22.2	54.7
Agave *Agave americana* (Arizona)	8.0	0.0	33.0a	35.2	24.0	92.1
Oil palm *Elaeis guineensis* (Indonesia)	34.0	17.0	128.8b	149.4	50.9	329.2
SRC Willow *Salix* "hybrids" (Sweden)	10.0	0.0	0.0	43.9	30.0	73.9
SRC Poplar *Populus* "hybrids" (Italy)	14.0	0.0	0.0	61.5	42.0	103.5
SRF Eucalyptus *Eucalyptus* "hybrids" (Brazil)	18.2	0.0	0.0	80.0	54.5	134.5

Source: Biofuels Digest, 2013.

Box 2: Key R&D issues concerning advanced biofuels. Source: Adapted from IEA (2011)[9]

Technology	Key R&D issues
Cellulosic-ethanol	Improvement of micro-organisms and enzymes. Use of C5 sugars, either for fermentation or upgrading to valuable co-products. Use of lignin as value-adding energy carrier or material feedstock. Feedstock handling and processing in cellulosic plants.
HVO	Feedstock flexibility. Use of renewable hydrogen to improve GHG balance.
BtL-diesel	Catalyst longevity and robustness. Cost reductions for syngas clean-up. Efficient use of low-temperature heat.
Other biomass-based diesel/kerosene fuel	Reliable and robust conversion process in pilot and demonstration plants.
Algae-biofuels	Energy- and cost-efficient cultivation, harvesting and oil extraction. Nutrient and water recycling. Value-adding co-product streams.
Bio-SNG	Feedstock flexibility. Syngas production and clean-up.
Pyrolysis oil	Catalyst improvement to exhibit oil stability over time. Upgrading to fungible biofuel.

Feedstock and sustainability

Dates	Milestones for feedstocks and sustainability
2010-50	Increase biofuel production based on "low-risk" feedstocks (e.g. wastes and residues) and through yield improvements.
2010-20	Reduce and eventually abolish tariffs and other trade barriers (e.g. logistical) to facilitate biomass and biofuel trade.
2010-30	Improve biomass potential analysis with better regional and economic data, including from large-scale field trials.
2010-30	Enhance biomass cascading and use of co-products through integration of biofuel production in biorefineries.
2010-20	Continue alignment of LCA methodology to provide a basis for sound support policies.

For all biofuels, there is scope for cost reductions that will help to improve competitiveness with fossil fuels and drive commercial deployment:

- Capital costs are expected to come down as a result of scaling up (particularly for advanced biofuels). Co-location with existing biofuel plants, power plants or other industrial facilities reduces capital costs and can bring further benefits such as the more efficient use of by-products.
- Conversion costs can be brought down through scaling up and technology sharing. Further improvement of conversion efficiency (e.g. through more efficient enzymes) and energy efficiency should also help to reduce costs.
- Feedstock costs cannot be predicted and are subject to agricultural commodity prices, oil prices and other factors. Enhancing feedstock flexibility will create access to a broader range of biomass sources with potentially low costs (such as residues) and reduced price volatility. Improving and creating transport infrastructure could further reduce biomass supply costs.

Source: Adapted from Biofuels Digest (2015).

US and 4.105–6.105 ton/year in Japan (Pugazhvadivu and Jeyachandran, 2005).

Another waste product for the production of biodiesel is the fat derived from animals. There are different types of animal fats that are used to produce biodiesel, such as tallow, lard, chicken fat and yellow fat. Animal fats are provided by the slaughtering industry, and are an alternative for the production of biodiesel, as they represent an affordable production feedstock. However, there are some processing disadvantages, such as high viscosity and difficulties in processing (Bhuiya, et al., 2015).

There are many energy crops that will be an important part of the future feedstock mix. However, exploitation of these emerging feedstock crops will require investment in breeding and agronomy to further enhance yields and adapt varieties to a wider range of environments, including future climates. Table 5 below gives the biomass, biofuel and bioenergy yields per hectare of the different feedstocks considered in major regions of current and potential production.

According to Long et al. (2013) it should be noted that yield ranges for all crops are very large and are variety, site and management-style dependent. It is assumed that 536, 380 and 342 litres of ethanol can be produced from 1 tonne of sucrose, lignocellulose and maize grain respectively, and that dry sugarcane stem and agave shoot has a sugar content of 33 percent. The oil content of rapeseed, soybean and oil palm are assumed to be 36 percent, 23 percent and 30 percent, and that 80 percent of the lipid can be recovered as biodiesel.

It is widely appreciated that different crops will be required to provide feedstocks for bioenergy and biofuels, particularly when considering the production of second-generation biofuels.

With this in mind, support should be given to further improve crop yields in a sustainable manner, for example through genomics and biotechnology combined with agronomic improvement.

Considerable advances have been made in the improvement of crop yields and in the understanding of the key criteria that need to be met for more sustainable production, as well as which crops best meet these criteria and the further changes needed to further improve sustainability. The challenges of meeting feedstock supply through yield improvement and the expansion of feedstocks in more sustainable ways can be met, but only with secure and prolonged support and sensible, easily adoptable policies that recognize the environmental as well as economic objectives. However, these policies are needed now along with strategies for increasing feedstock production in sustainable ways that can be implemented immediately (Long et al., 2013). As costs and production potentials are closely tied to conversion pathways, the International Renewable Energy Agency (IRENA) is developing a report with a strong focus on second-generation biofuels, which will be launched in early 2016.

5. SECOND-GENERATION BIOFUELS: FROM PROMISE TO REALITY

Second-generation biofuels have evolved independently of previous generation biofuels. They instead represent products from new industrial dynamics, which have become part of the so-called bioeconomy, in which biomass-based products have been increasingly available as food, feed, energy and biomaterials.

Second-generation biofuels can be a lower carbon option than first-generation biofuels in terms of their effects.

According to the International Energy Agency (IEA), second-generation biofuels are produced from cellulose, hemicellulose or lignin. Such biofuels can be blended with petroleum-based fuels or used in adapted vehicles (IEA, 2010). Cellulosic ethanol and Fischer-Tropsch fuels are an example of second-generation biofuels. Second-generation biofuels yield greater energy output than fossil fuels, include a much larger array of feedstock options (Carriquiry et al, 2011), minimize competition on land and have much less environmental impacts.

A 50 percent growth in the second-generation biofuels market has been forecast between 2014-2020 and its value in 2020 has been estimated to amount to US$ 23.9 billion (Allied Market Research, 2014). Navigant Research (2014) forecasts that global biofuel consumption in the road transportation sector will grow from more than 122.6 billion litres per year in 2013 to more than 193.41 billion litres per year in 2022, which will increase demand for advanced biofuels. In the last ten years, an increase in ethanol production capacity in the US and Brazil, and biodiesel in Europe, has resulted in biofuels gaining an important position in the global market for liquid. However, the biofuels market is highly fragmented as over a hundred companies in different countries participate in the market and base their production on various types of second-generation biofuels.

In the global liquid fuel market, biofuels have been particularly prominent in many countries and the production and consumption of biofuels such as ethanol and biodiesel has been growing rapidly (Carriquiry et al, 2011). However, despite their huge potential, biofuels still face the challenge of feedstock access, supply chain infrastructure development, and the price parity with the petroleum industry; all of which are essential to create new markets.

Despite the extensive use of biomass as a source of energy production, some developing countries still depend on oil imports to satisfy their energy demand, which makes them vulnerable to high and volatile oil prices. Some countries, such as China, Brazil, Thailand and India, developed a strong first-generation biofuel sector that led to a significant production capacity and infrastructure (OILGAE, 2015). Countries that have a strong regulation and government funding for research in this area, such as North America and Europe, are gaining the majority market share, but until 2020 this scenario might change (ALLIED, 2015). Currently most of the second-generation biofuels, such as cellulosic ethanol and biomass-to-liquid biodiesel, otherwise known as advanced biofuels, are in the early phases of commercialization or still in the pilot production phase (biobutanol and bio dimethyl ether - bioDME).

Since 2006, the economies that have dominated the market are Brazil, the US and the EU, which have traditionally had the greatest influence due to their supportive regulations and governmental incentives for biofuel production.

Table 6: World installed capacity of cellulosic ethanol

Region	2G Ethanol installed capacity (million litres)	Percentage of world total
US	490.37	34%
China	340.19	24%
Canada	303.45	21%
Brazil	177.34	12%
EU	130.83	9%
World (2015)	1 442.18	100%

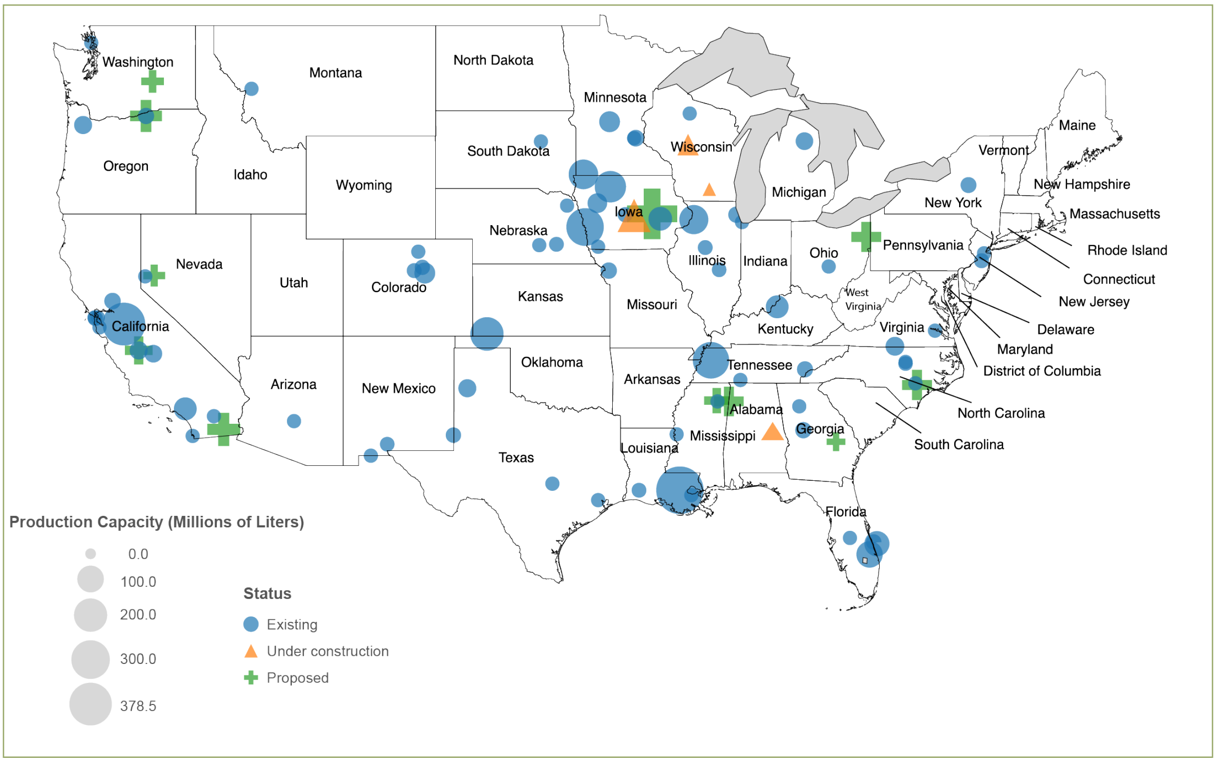
While developing countries such as China, Brazil, Thailand and India developed a strong first-generation biofuel sector (UNCTAD, 2014), Thailand and India, for example, had not made much progress on cellulosic ethanol as of 2015. However, there are potential demand-pull sources in markets such as the US - where cellulosic ethanol imports are expected to meet national mandates that could create incentives for a broader basket of developing countries to join the pool of producers. This is especially valid if advanced biofuels production does not increase in US in tandem with its blending ambitions.

5.1 United States

According the US Energy Information Agency (2015c), biofuels comprised of five percent of total fuel utilized in the transportation sector in 2014, which leaves considerable potential for advanced biofuels to increase this share in the coming decades. Of the biofuels used in the transportation sector, light-duty vehicles predominantly use E-10, a gasoline-ethanol blend that contains 10 percent ethanol. While the Environmental Protection Agency (EPA) confirmed that the use of E-15 in conventional vehicles of model year 2001 and newer passes engine safety requirements, blends higher than 15 percent require the use of fuel-flex vehicles (United States Department of Energy (DOE), 2014b; EPA, 2015). Additionally, light-, medium-, and heavy-duty vehicles designed for diesel fuel can also accommodate biodiesel, with B-20 and B-5 being the most common blends (DOE, 2014a). Despite some setbacks resulting from regulatory uncertainty, feedstock challenges, and infrastructure shortcomings, many second-generation biofuel companies continue to move towards commercialization (Environmental Entrepreneurs (E2), 2014).

Based on a compilation of multiple datasets (Biofuels Digest, 2012; Biofuels Digest, 2013; Ethanol Producer Magazine, 2015; United States Department of Agriculture Economic Research Service (USDA), 2014; Renewable Fuels Association (RFA), 2015a) and an examination of company profiles, 115 facilities were identified (of which 39 are cellulosic facilities) in the US as of mid-2015—including those under construction and proposed. Facilities that produce more progressive advanced fuels, such as renewable drop-in fuels (RDIF) and renewable chemicals, were included in the data plot in Fig. 9 in addition to second-generation bioethanol and biodiesel facilities. Since the industry is experiencing ongoing change, each dataset examined contained a different number of second-generation production facilities. Environmental Entrepreneurs (2014), for example, identified 167 US commercial facilities working on advanced biofuels. This comparison does not necessarily imply a reduction in operating facilities. Instead, it provides a glimpse of the variability in current research concerning second-

Figure 8: Second-generation biofuel facilities in the US



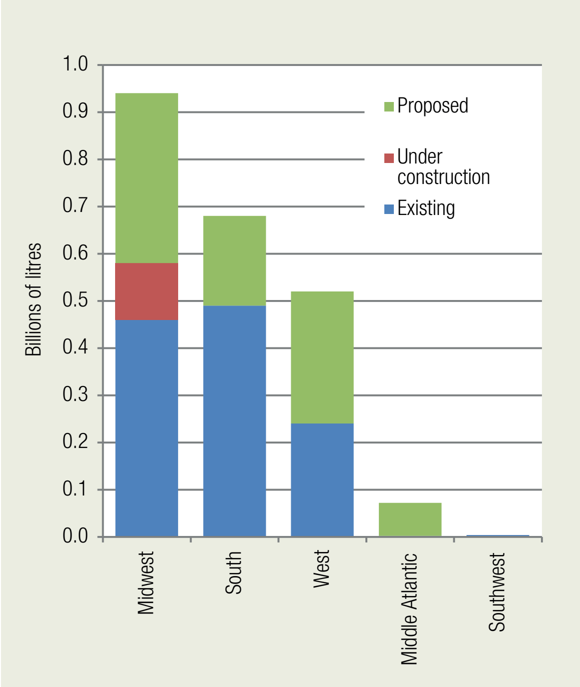
Sources: Biofuels Digest, 2012; Biofuels Digest, 2013; Ethanol Producer Magazine, 2015; USDA ERS, 2014; RFA, 2015a. Credits: Duke Center for Sustainability & Commerce.

generation biofuels, and the data provided seeks to convey the most current snapshot of this rapidly changing industry.

The dataset reveals several characteristics about second-generation biofuel production in the US. Of the 115 facilities identified (for all types of advanced biofuels), cellulosic ethanol facilities represented 39 plants, totalling about 1.37 billion litres of installed capacity. Taking a more conservative approach of considering only existing facilities and those under actual construction (thus excluding the proposed cellulosic facilities), this number rounds to 29 facilities with a combined 490.37 million litres of installed production capacity in the US in 2015. Production capacities, as well as facility locations, are closely linked with feedstock availability. As such, the majority of second-generation biofuels are produced in the Midwest where there is a large stock of corn stover (National Renewable Energy Laboratory (NREL), 2012). The E2 group forecasts a significant increase in advanced biofuel production in the coming years, with a low 2017 projection of 4.06 billion litres and a high 2017 projection of 6.50 billion litres (E2, 2014).

While historically cellulosic biofuel production levels have been low, the industry has experienced significant progress in recent years. The commercialization of cellulosic ethanol became a reality in 2013 when INEOS Bio, using numerous feedstocks including vegetative waste, agricultural waste, and municipal solid waste, completed construction of its facility in Vero Beach, Florida (Lane, 2015). In 2014, the cellulosic ethanol industry witnessed another landmark

Figure 9: US second-generation biofuel production by region



Source: Biofuels Digest, 2012; Biofuels Digest, 2013; Ethanol Producer Magazine, 2015; USDA ERS, 2014; RFA, 2015a.

Table 7: Existing commercial facilities producing second-generation fuels with the highest production capacities

Facility	2G fuels produced	Production capacity (million litres)	City	State
Dynamic Fuels (REG)	Renewable diesel, RDIF	283.91	Geismar	Louisiana
Aemetis	Ethanol	208.20	Keyes	California
NatureWorks	Renewable chemicals	140.06	Blair	Nebraska
EcoSynthetix	Renewable chemicals	126.24	Dyersburg	Tennessee
Abengoa	Ethanol	94.64	Hugoton	Kansas
POET-Project Liberty	Ethanol	75.71	Emmetsburg	Iowa
Gevo	Biobutanol	60.57	Luverne	Minnesota
Metabolix	Renewable chemicals	56.78	Clinton	Iowa
LS9	Ethanol	37.85	Okeechobee	Florida
INEOS Bio	Ethanol	30.28	Vero Beach	Florida

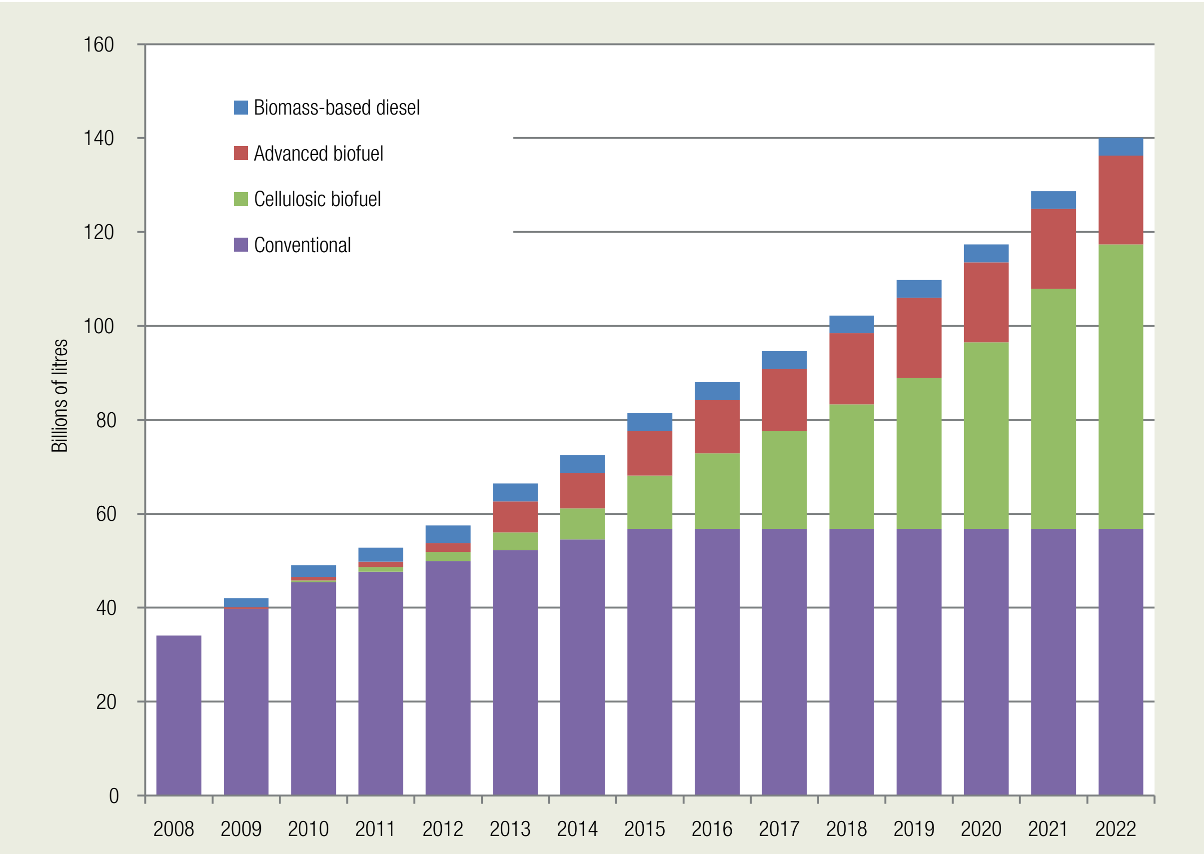
Sources: Biofuels Digest, 2012; Biofuels Digest, 2013; Ethanol Producer Magazine, 2015; USDA ERS, 2014; RFA, 2015a.

event when POET-DSM Advanced Biofuels LLC's Project Liberty began commercial operations. Two more plants became operational later that same year. As of 2015 the largest producers of cellulosic ethanol are INEOS Bio, POET, Abengoa, and Quad County Corn Processors (Congressional Budget Office, 2014; Fuels America, 2015). According to Ethanol Producer Magazine (2015), the actual cellulosic production for 2014 amounted to 124.92 million litres, which if compared to UNCTAD's estimated installed capacity in the US as of 2015 gives a utilization rate of approximately 25 percent (EPA, 2015). In comparison, conventional ethanol production capacity for 2014 is estimated at 56.79 billion litres (RFA, 2015b).

The most significant policy driver for biofuel production is the Renewable Fuel Standard (RFS). Created under the Energy Policy Act of 2005, the RFS mandates a minimum renewable fuel volume for transportation fuels sold in the US. The original RFS established a minimum requirement of roughly 28.39 billion litres of renewable fuel to be blended into gasoline by 2012 (EPA, 2014). In 2007 the passage of the Energy Independence and Security Act (EISA) altered the RFS in a number of ways in accordance with national goals to reduce dependence on foreign oil, promote biofuel use, and stabilize transportation fuel prices (Bracmort, 2015). Notably, the RFS expanded to include diesel, established new categories of renewable fuels, and increased the minimum renewable fuel volume to approximately 136.27 billion litres by 2022 (EPA, 2014).

The RFS places biofuels into four categories: (1) total renewable fuels, (2) advanced biofuels, (3) cellulosic biofuels, and (4) biomass-based biodiesel. Total renewable fuels represent the biofuel mandate from all feedstocks, placing a cap on the amount of conventional sources that can be used to meet standards following 2015. This mechanism induces the market to generate premiums for the more scarce, lower-carbon advanced biofuels such as advanced

Figure 10: Renewable Fuel Standard volumes by year



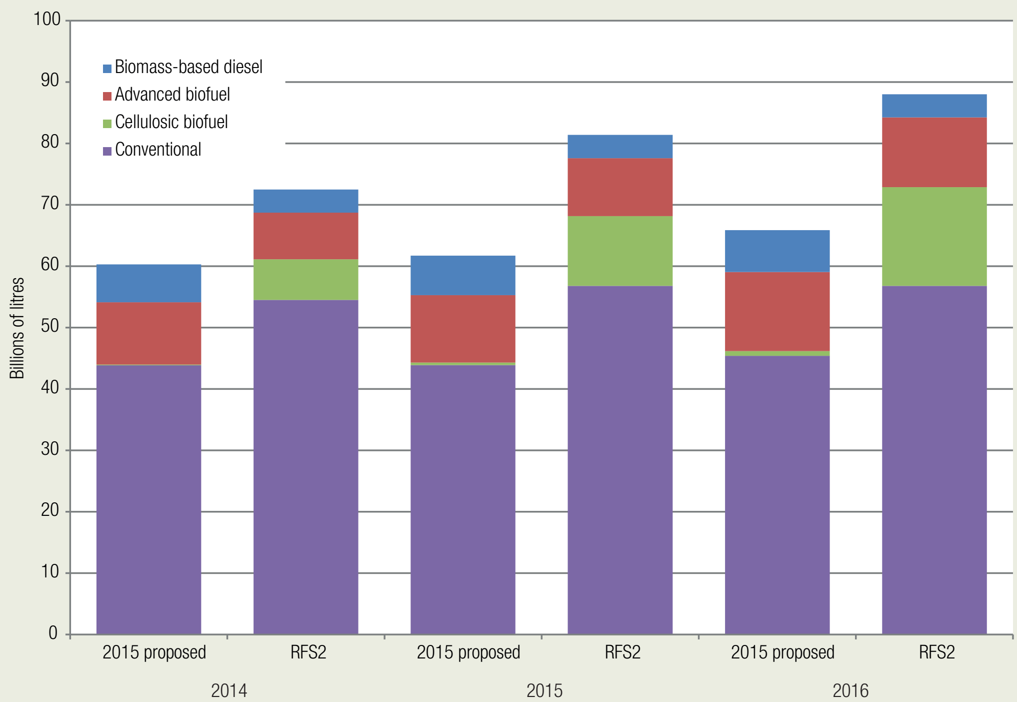
Source: Projections from the Alternative Fuels Data Center, 2012.

and cellulosic types. To qualify as advanced biofuels, the RFS does not consider the feedstock type approach, but instead the GHG performance of the biofuel, which must reduce lifecycle GHG emissions by 50 percent when compared to fossil fuels. A variety of potential feedstocks, excluding cornstarch, are identified as advanced fuels within this category. Similarly, cellulosic biofuels must reduce lifecycle GHG emissions by 60 percent. Any diesel fuel that is produced from biomass feedstocks and meets a lifecycle GHG emissions reduction of 50 percent qualifies for the biomass-based biodiesel category (Schnepf & Yacobucci, 2013).

As part of the implementation of the RFS, the EPA uses Renewable Volume Obligations (RVOs and Renewable Identification Numbers (RIN) to ensure that refiners, blenders, and importers of petroleum-based gasoline and diesel fuel meet renewable fuel standards. RVOs set target percentages that correspond to the required renewable volumes of biofuels for each year. RINs then help track targets and allow for flexibility in meeting standards. When produced, each qualifying gallon of renewable fuel is given a unique RIN 38 digit alphanumeric code. Obligated parties can meet compliance by either generating their own RINs by blending physical quantities of biofuels or through purchase from the RIN market. A supplier that has an excess of RINs can sell them or save them to use the following year. All RIN transactions must be cleared through the EPA's in-house system, the EPA Moderated Transaction System (EMTS). While most RINs are bought and sold through private contracts registered within the EMTS, there are also spot markets for RINs (EIA, 2013).

While the RFS has been the strongest policy driving the US biofuels market to increase production levels, recent uncertainty surrounding the RFS during the past year disrupted market expansion. The EPA delayed release of 2014 volumetric requirements as a response to concerns of having reached the E-10 "blend wall." The "blend-wall" refers to the inherent difficulty in incorporating more than 10 percent

Figure 11: Comparison of proposed RFS mandates to 2007 RFS-2 mandates



Sources: Alternative Fuels Data Center, 2012; EPA, 2015.

ethanol (E-10) into traditional fuels. The EPA delayed the release of volumetric requirements for five months until May 2015, when they proposed changes to lower production level requirements for 2014, 2015, and 2016. In addition, the EPA attributed these changes to a lower than predicted level of gasoline consumption that hindered demand for ethanol blending (E2, 2014). The EPA's draft 2014 renewable fuels volumes, which are to be finalized by November 30, 2015, are set at actual production levels for the year - 60.30 billion litres. Reduced volume levels for 2015 and 2016 are set at 61.70 billion litres and 65.87 billion litres, respectively. Within these total volume proposals, the cellulosic biofuels category received the greatest reduction in volumetric requirement compared to RFS-2 mandates. Nevertheless, by 2015 the EPA proposes nearly tripling cellulosic biofuel production from 2014 levels, and the proposal mandates for 2016 almost doubles the requirement from 2015 (EPA, 2015). Future investments in more efficient cellulosic ethanol technologies depend on RFS mandates. Since the EPA also missed the specified deadline for announcing annual production mandates in the years prior to 2014, stakeholders are growing increasingly frustrated over delayed RFS mandates due to the potential implications this uncertainty has on the biofuels market for producers and investors (Henry, 2015).

In the first six months of 2015, the US biofuels market generated a number of RINs in each biofuel category. RINs are divided into several categories, with D4 representing biomass-based diesel, D5 corresponding with advanced biofuels, and D6 accounting for renewable fuel. The market generated nearly 1.3 billion D4 RINs for bio-based diesel, with levels of RIN generation increasing significantly in May and June at about 265 million RINs per month. In June of 2015, D5 cellulosic ethanol amounted to approximately 39 million RINs. In addition, D6 RINs for corn ethanol expanded at a relatively steady pace, totalling 7.2 billion. Assuming this pace continues, the total number of RINs generated in this category could reach more than 14.5 billion by the end of 2015. If these trends continue, the likelihood of meeting 2015 proposed mandates for advanced ethanol and total renewable fuel is high. The high production rates of D6 corn ethanol also would result in the US having the potential to export over 3.78 billion litres of ethanol (Paulson, 2015). RINs make use of trade markets, whereby obligated parties purchase RINs to meet targets or sell excess RINs. When production is not meeting yearly mandate requirements, RIN prices rise to incentivize production. In the case of increased ethanol production, the industry is compelled to invest in technologies that can move past the E-10 "blend wall" constraint (Peterka, 2015).

In 2014, the cellulosic biofuel industry, which includes cellulosic ethanol, cellulosic naphtha, renewable gasoline and biogas derived from Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG), generated 33.0 million RINs. The cellulosic ethanol volume mandates were introduced in 2010 but were consistently revised because until 2014 there was no large-scale production. In the case of cellulosic ethanol, there is also the Cellulosic Biofuel Waiver Credit (CWC), which has counter-cyclical compliance value for cellulosic biofuels that increases as the petroleum price decreases. EISA establishes that the amount of the CWC is between US$ 0.25 and US$ 3.00 per gallon. In recent years, the CWC has declined (Table 9) but the EPA recently revised the calculation methodology of the CWC and under the new rules the CWC value for 2014 is US$ 0.49 and in 2015 will be US$ 0.64.

In order to be successful, the industry requires that advanced biofuels become cost-competitive with petroleum-based fuels. Outside of the RFS, a number of federal and state policies exist that create incentives for producers and the entirety of the supply chain in an attempt to make advanced biofuels more economically attractive. Government agencies, particularly the DOE and the USDA, provide grants, loan guarantees, and other sources of funding to spur investment in second-generation development. Over US$ 1.7 billion in public support from federal agencies and states has helped

Table 8: The value of advanced RIN, Cellulosic Waiver Credit and Cellulosic RIN, 2011-2013

	Advanced RIN (D5) value US$/GEE (average)	Cellulosic Waiver Credit US$/GEE	Cellulosic RIN (D3) Value
2011	0.75	1.13	1.88
2012	0.62	0.78	1.40
2013	0.82	0.42	1.24

Sources: USDA, 2014; Bracmort, 2015; California Environmental Protection Agency, 2015.

fund producers and other supply chain companies since the RFS was enacted in 2007 (E2, 2014). Prior to 2015, the US government did not prioritize funding for the bio-based industry as a whole, focusing instead on bioethanol and biodiesel transportation fuels. However, funding sources are now expanding to include opportunities for the broader bio-based industry. The USDA BioRefinery Assistance Program, which receives funding from the 2014 Farm Bill, is one example of such an opportunity. In June 2015, the USDA announced changes to the programme, expanding loan guarantees to producers of renewable chemicals and bio-based products in addition to advanced biofuels. Industry's reaction to this policy incentive has been positive, as the initiative enables innovative emerging biotechnology companies to qualify for USDA loan guarantees and further boosts investment opportunities (Voegele, 2015).

The inclusion of bio-based products in the BioRefinery Program partially can be attributed to the rapidly growing consumer demand for bioproduct development and production. This includes biochemicals, bioplastics such as Coke's Plant Bottle, and intermediate products such as the variety of internal automobile components used by the Ford Motor Company. In addition to the amended BioRefinery Assistance Program, the USDA also has a BioPreferred Program that certifies bioproducts and places them on a registry. This programme, as well as the increasing demand to incorporate lifecycle assessments of products from retailers and brands, is seen to be a key driver for second-generation feedstocks (Golden et al., 2015; Golden & Handfield 2014 & 2015; Morrison and Golden, 2015).

Another example of a tax incentive is the Bonus Depreciation for Renewable Power, Biodiesel, Diesel and Green Cellulosic Biofuels. According to the Energy Law Journal (2008), the inclusion of cellulosic biofuel in bonus depreciation for biomass ethanol plant property allowed "a bonus depreciation allowance for biomass ethanol plant property producing any kind of cellulosic biofuel. Before the Act was enacted, fuel producers could write off fifty percent of the cost of facilities that produce cellulosic biomass ethanol (for facilities placed in service before January 1, 2013). This tax benefit is available for facilities that produce other cellulosic biofuels (e.g. biodiesel)".

In addition to the Departments of Energy and Agriculture, the US Department of Defence (DoD) recently became an active player in the push for

Table 9: The three most important federal regulations driving biofuels in the US

Key Legislation in the US	
Farm Security and Rural Investment Act of 2014	The Act sets a primary legal framework for agricultural policy through a legislative process that occurs approximately every five years. Among other provisions, the Act expands initiatives for bioenergy. It reauthorizes existing funds established in the 2008 Farm Bill and provides a total of US$ 880 million for energy programmes.
Energy Policy Act of 2005 & Energy Independence and Security Act (EISA) of 2007	The Energy Policy Act of 2005 calls for the development of grant programmes, demonstration and research initiatives, and tax incentives that promote alternative fuels and increase production and use of advanced fuels. The Energy Independence and Security Act encourages the development of alternative fuels in order to expand domestic sources of transportation fuel. EISA establishes the RFS-2 and includes grant programmes to encourage the development of cellulosic biofuels, plug-in hybrid electric vehicles, and other emerging electric technologies.
California Low-Carbon Fuel Standard (LCFS)	California's Low Carbon Fuel Standard, established in 2007, requires a 10 percent reduction in the carbon intensity of the state's fuel mix by 2020. The LCFS was the first policy to make use of market-based mechanisms in an attempt to lower transportation emissions. In 2014 the California Environmental Protection Agency froze LCFS levels at 2013 compliance levels due to concerns from industry. Advanced biofuels most likely will play a major role in meeting this objective, with some reports estimating that advanced biofuels could contribute up to 50 percent of overall carbon intensity reductions (E2, 2014). The LCFS is currently awaiting re-adoption with the inclusion of several new amendments from the past year.

Sources: USDA, 2014; Bracmort, 2015; California Environmental Protection Agency, 2015.

Table 10: Public investments for second-generation biofuels between 2007-2014

	Grants (million US$)	Loan guarantees (million US$)	Totals (million US$)
Department of Energy	541.7	133.9	756.2
Department of Agriculture	25.6	573.5	599.0
Department of Defence	225.3	0.0	225.3
Totals	847.9	707.4	1 718.3

Sources: E2, 2014.

advanced biofuel development, striving to use cost-competitive renewable drop-in fuels in aircraft and the marine fleet. In the fall 2014, the DoD, with the Navy as the main advocator, awarded US$ 210 million to three biorefineries capable of producing drop-in fuels, including Emerald Biofuels, Fulcrum BioEnergy, and Red Rock Bio. Once complete, these players will have a combined capacity for producing 378 million litres of military-spec fuel, with initial production as early as 2016 (Lane, 2014). These drop-in fuels are capable of being blended at a 50/50 ratio with fossil fuels, allowing the DoD to use these fuels without hindering performance. As the production of advanced drop-in biofuels becomes more readily available, the US Navy intends to include these fuels as a regular part of its fuel procurement, with biofuels making up 50 percent of the fuels used by ships and aircraft throughout the fleet by 2016 (US DoD, 2014; Matsunaga, 2014).

Grants and loans for second-generation biofuels from the Departments of Energy, Agriculture, and Defence totalled over US$ 1.7 billion between 2007 and 2014 (E2, 2014). These funds, as well as tax incentives, government vehicle policies, and price incentives to blend and sell higher blends of ethanol, are put forth by federal and state governments to support the industry in overcoming a multitude of barriers. Some barriers include the high capital costs associated with production, stability and diversity of feedstocks, and low consumer demand associated with a lack of infrastructure for higher ethanol blended fuels (Huentler, Anadon, Lee, & Santen, 2015).

In terms of high capital costs, POET-DSM reports that its 75 billion litre per year production facility costs approximately US$ 250 million in capital costs (Potas, 2013). DuPont's cellulosic ethanol plant, which is currently under construction, is expected to cost US$ 225 million by completion (Dupont, 2013). Since 2007 financial investment in biofuel producers and value chain companies amounted to over US$ 3.7 billion in private equity and more than US$ 550 million in debt financing (E2, 2014). In this respect, government incentives were very important. According to the AEC Cellulosic Biofuels Industry Progress report (2012-2013):

- INEOS received US$ 50 million from a DOE grant, US$ 75million from the USDA loan guarantee and US$ 2.5 million (State of Florida) grant.
- Abengoa Bioenergy Biomass of Kansas was selected by the DOE for US$ 97 million Section 932 Cost Share Grant and awarded EPAct 2005 loan guarantee in 2011 for development.
- Poet-DSM received US$ 100 million in grants from DOE; US$ 14.8 million grant from the State of Iowa for bio-refinery construction, engineering and feedstock acceleration activities; and US$ 5.25 million in credits from State of Iowa for tax and training.

Many investors are unlikely to assume the risk of these high costs for second-generation biofuel commercial plants without certainty that the RFS will create a strong regulatory environment that mandates production volumes for long-term development. This is reflected in lower investment figures since the fourth quarter of 2013 and into 2014, with proposed projects impacted most severely (E2, 2014).

However, these financial risks are likely to decrease over time as more large-scale commercial plants become operational (Bracmort, 2014). In addition, some experts are pushing for distributed smaller-scale operations that could prove more resilient to policy changes. As the policy structure currently stands, investments are only feasible when they add to existing physical infrastructure for producers and supply chain companies instead of attempting to fund the construction of new commercial facilities (Huenteler, Anadon, Lee, & Santen, 2015). Therefore, instead of investing in new commercial facilities, these distributed smaller-scale operations would add new technologies to conventional facilities that produce advanced feedstocks (E2, 2014). Furthermore, producers may shift interest to the West Coast, particularly California, where the Low Carbon Fuel Standard (LCFS) provides a more certain policy forecast (E2, 2014).

Commercialization of second-generation biofuels must also overcome uncertainty surrounding feedstock reliability, as supply chains for such feedstocks are relatively new (EPA, 2013). Therefore, in the US cellulosic biorefineries tend to prefer more secure, multi-year contracts with suppliers in order to ensure better projections of operating and maintenance costs for the facility (Bracmort, 2014). Suppliers of feedstocks are typically hesitant to enter into a long-term contract with cellulosic producers, as these feedstocks require additional delivery expenses due to the decreased energy density of advanced feedstocks compared with conventional feedstocks. To overcome this barrier, the DOA implemented a Biomass Crop Assistance Program (BCAP) that provides US $25 million each year until the end of 2018 to assist farmers and forester landowners in establishing, producing, and delivering new sources of biomass for energy or bio-based products (USDA, 2015). BCAP provides incentives for producers across more than 48,000 acres in 71 counties with 11 designated project areas. In August 2015, the USDA expanded the opportunities available under the programme by encouraging producers to submit proposals for new BCAP project areas (USDA, FSA, 2015).

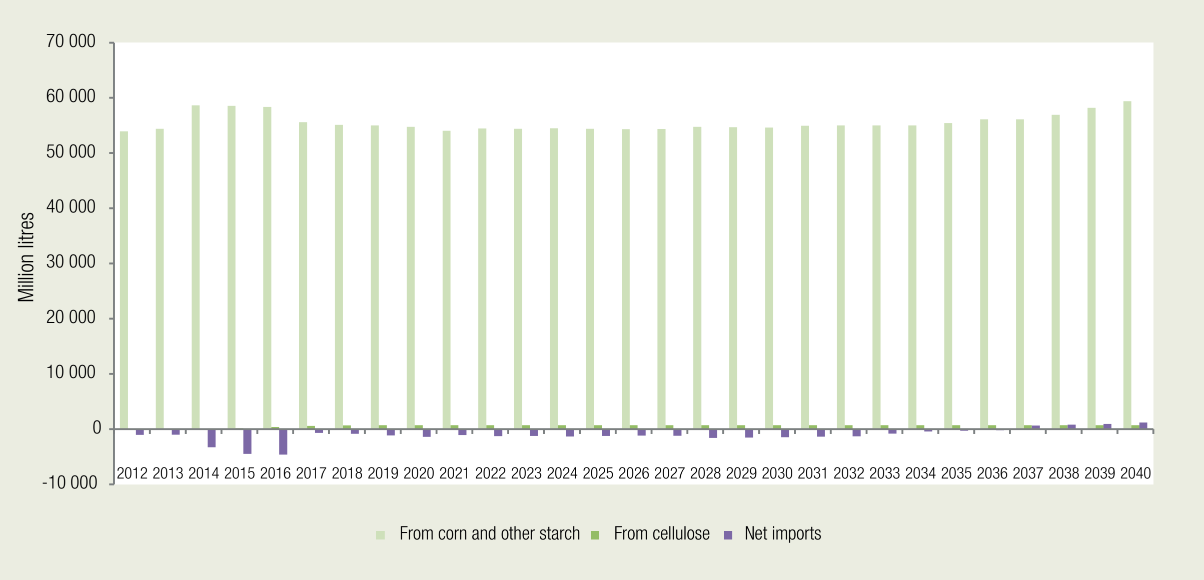
On the demand-side of bioethanol, the dominant biofuel in the US, concerns persist over the highly publicized "blend wall." When the EPA released RFS-2 in 2007 projected gasoline consumption levels were much higher than what what was realized. Due to this, the EPA anticipated a higher market demand for ethanol, but instead the market reached the 10 percent "blend-wall" at much lower volumes of ethanol and is now saturated with E-10. Therefore, any growth in cellulosic ethanol requires bioethanol consumption to overcome this constraint (Huentler et al., 2015). In fact, the newly proposed RFS mandates for 2016 require that refiners break through this limit (Peterka, 2015). The EPA proposed that E-85—a higher ethanol blend—be expanded throughout the country for US consumers with flex-fuel vehicles (Beckman, 2015). Refiners, however, hold the opinion that E-85 alone will not add enough ethanol to the market (Peterka, 2015). Another option to break through the "blend-wall" is through the widespread adoption of E-15 within the existing vehicle fleet. Widespread use of either E-15 or E-85 requires that existing service station pumps, storage tanks, and other associated infrastructure elements be retrofitted or replaced (Davis, Diegel, Boundy, & Moore, 2015).

As previously mentioned, the EPA approved use of E-15 in conventional vehicles. However, due to strong resistance from the oil industry, concerns from vehicle manufacturers, and the inability of smaller engines to operate on blends higher than E-10, the proposed RFS mandates do not mention any new ruling to require higher ethanol blending of E-15 (EPA, 2015). Despite this lack of requirement, the USDA announced in May 2015 that US$ 100 million is available through the Biofuel Infrastructure Partnership (BIP) (USDA, 2015). The BIP awards competitive federal grants, matched by states, to expand the infrastructure for higher blends of ethanol at the pump. The federal agency estimates that this investment could more than double the number of fuelling stations in the US that offer E-85 and E-15 (USDA, 2015). Nevertheless, some experts argue that encouraging consumption of these higher blend fuels poses additional challenges (Huentler et al., 2015). For example, ethanol has a lower energy density than gasoline, which decreases consumer mileage when driving on ethanol. As a result, higher blends of ethanol need to be priced lower per litre in order for consumers to reap the same economic and mileage benefit that gasoline and lower ethanol blends afford.

RDIFs are a promising solution for the industry to overcome the E-10 "blend-wall" and leverage current infrastructure in the US. RDIFs, also referred to as "green" hydrocarbons, are produced from biomass sources through a range of new technological processes, including gasification or pyrolysis. These fuels have a chemical makeup so similar to petroleum-based fuels that they require no additional infrastructure for distribution and are compatible with existing engines. The NREL and the National Advanced Biofuels Consortium (NABC) have driven much of the research in this emerging field in the US since 2010. While commercialization is moving slowly, support from the DoD recently demonstrated the potential for larger-scale deployment of these fuels (Alternative Fuels Data Center, 2015; DoD, 2014).

Several crucial federal advanced biofuel tax incentives expired at the end of 2014, which prompted a number of biofuel trade organizations to send a letter to Congress in July 2015 urging for their renewal (Reuters, 2015). The Senate Finance Committee heeded their concerns and passed a tax extenders package

Figure 12: Current and estimated cellulosic ethanol production in the United States



Source: Annual energy outlook 2015 - US Energy Information Administration.

that includes a two-year extension of tax credits for biodiesel, renewable diesel, and cellulosic biofuels until the end of 2016. Specifically, the bill contains a provision extending a US$ 1.01 per gallon production tax credit for cellulosic biofuels, as well as a US$ 1.00 per gallon credit for biodiesel and renewable diesel (Kotbra & Voegele, 2015). While a positive signal for the cellulosic industry, some experts suggest that an investment tax credit is more attractive at this stage of cellulosic technology development (Huentler et al., 2015).

In addition, Congress amended the biodiesel fuels tax credit from a mixture tax credit to a producer tax credit in an attempt to ensure that the credit benefits only domestic biodiesel production and does not subsidise imported biofuels. This amendment goes into effect on 1 January 2016. The ruling also extended the alternative fuel mixture excise tax credit and a special depreciation allowance for second-generation biofuel plant property. As of 30 September 2015, the legislation is awaiting consideration from Congress (Kotbra & Voegele, 2015). Despite the renewal of the biodiesel fuels tax credit, the period during which the tax credit had expired and the uncertainty around the RFS placed additional pressure on the biodiesel industry. Without a certain market in which to sell their product, some biodiesel plants are running at lower capacities or halting production (Barton, 2015).

A number of states have stepped in to implement their own incentives to spur the development of second-generation biofuels beyond federal initiatives. The number of incentives and laws varies from state to state, with the maximum number of incentives for ethanol at 14 per state in California, Indiana, Illinois, Washington, and Minnesota. Similarly, a number of states have incentives for biodiesel, with Washington and Virginia holding the highest number of biodiesel incentives at 17 per state (Alternative Fuels Data Center, 2014).

Policies impact not only the domestic market for biofuels, but also the international market. Trade of biofuels between the US and the global market experienced a shift in 2010 when the US became a net exporter of biofuels, partly as a result of the RFS. Since the RFS limits the amount of biofuels derived from conventional sources that can be used to meet requirements, this cap could potentially lead to increased exports in order to make use of existing infrastructure. In the long run, however, this policy could lead to a reduction in US ethanol derived from conventional sources, thus limiting the supply available for export. Additionally, if the advanced biofuel market does not grow in the US and production stalls at current capacity, advanced biofuel requirement volumes will need to be met by imports (Beckman, 2015), as seen in the figure below.

Policies such as the RFS will continue to impact the future global biofuel trade. Due to the uncertainty surrounding the RFS, for example, biodiesel and renewable diesel imports fell 36 percent in 2014 compared to 2013 levels, with total imports amounting to roughly 1.26 billion litres. Canada supplied 47 percent of the US's biodiesel imports, while Indonesia and Argentina supplied the remaining majority share of biodiesel imports (EIA, 2015b). In terms of ethanol trade, the US exported approximately 3.13 billion litres of ethanol in 2014, second only to exports in 2011. Canada received the majority of these exports, followed by Brazil, the United Arab Emirates, and the Philippines who all received at least 189 million litres of ethanol. Furthermore, uncertainty around the RFS, and in particular requirements for advanced biofuels, caused the US to import less sugarcane-based ethanol from Brazil (EIA, 2015a).

5.2 Europe

While biofuels have been marketed in Europe shortly after the introduction of the first biofuels directive in 2003, reinvigorated mandates and sustainability requirements for biofuels were not introduced in the EU until 2009 (European Parliament, 2009). In 2015, the average blending of conventional ethanol and biodiesel in the EU fuel pool was estimated to be 3.3 percent and 4.3 percent respectively (USDA, 2015). The amended Fuel Quality Directive (European Parliament, 1998) and the Renewable Energy Directive (European Parliament, 2009) include a number of sustainability criteria for biofuels. Compliance with these criteria is required for biofuels to count towards the set national renewable energy and fuel blending targets as well as making them eligible for financial support (European Commission, 2010).

The current sustainability legal framework under both Directives is summarized in the following table.

The sustainability criteria envisaged in the Renewable Energy and the Fuel Quality Directives contain both biodiversity and carbon-stock related criteria (non-use of peatlands) (Romppanen, 2012). At the same time, advanced biofuels produced from waste and industrial residues only have to comply with greenhouse gas emission saving targets as they do not concern other sustainability issues[11]. Whereas the EU sustainability criteria are considered to be the strictest in the world (European Commission, 2011), some critics expressed their concerns that the indirect land-use change (iLUC) was neglected in the current legislation (European Parliament, 2015). The Fuel Quality Directive mentions that 'land should not be converted for the production of biofuels if its carbon stock loss upon conversion can not be restored within a reasonable time period, taking into account the urgency of tackling climate change, be compensated by the greenhouse gas savings resulting from the production of biofuels' (European Parliament, 1998). A study commissioned by the European Parliament in 2011 suggested that land-use change (both direct and indirect) in the EU could be primarily caused by biofuel feedstock production (European Parliament, 2011). Current versions of both Directives address only the direct land use change emissions.

Based on the mandate contained in the Fuel Quality Directive (European Parliament, 1998) , the European Commission (EC) tabled a Proposal to limit the use of first-generation biofuels in 2012, which would potentially cause the iLUC (further referred to as iLUC-intensive biofuels) to the benefit from second-generation biofuels (further referred to as non-iLUC biofuels). From the perspective of the EU, measures to promote biofuels should focus on advanced biofuels, which have low-iLUC impacts and high overall GHG emission savings. Moreover, according to the EC 'almost the entire biofuel production in 2020 is expected to come from crops grown on land that could be used to satisfy food and feed markets. In light of these objectives, the Proposal introduced a seven percent cap at the EU level for the share of energy from biofuels from cereal and other starch-rich crops, sugars and oil crops and other crops grown as main crops primarily for energy purposes on agricultural land.

The proposal introduced by the EC in 2012 was not immediately passed and there was a long-standing debate in the European Parliament. Difficult discussions emerged when determining the cap for first-generation biofuels and the target for second-generation biofuels. Double counting methods and the ILUC reporting requirements were also debated; and this has caused the Council to extend the time on working for the proposal. A political agreement was finally reached in 2014 (in light of the European Parliament election in May 2014).[14]

On 28 April 2015, the European Parliament finally voted for the new amendment of EU Renewable Energy Directive (RED). The new law caps first-generation biofuels to account for no more than 7 percent (instead of 5 percent) of the energy consumed by transport in 2020; an indicative, non-binding 0.5

Table 11: current sustainability legal framework under the Fuel Quality and Renewable Energy Directives

Fuel Quality Directive	Renewable Energy Directive
Sustainability requirements for biofuels	
Sustainability Criteria (Art. 7b): • GHG emission savings from the use of biofuels – 35% (50% - 2017; 60% - 2018); • Not from land with high biodiversity as of 2008 (forest, designated protected areas, highly biodiverse grassland10); • Not from land with high carbon stock (e.g. wetlands); • Not from peatland as of 2008.	Sustainability criteria (Art. 17) (the same as in FQD): • GHG emission savings from the use of biofuels – 35% (50% - 2017; 60% - 2018); • Not from land with high biodiversity as of 2008 (forest, designated protected areas, highly biodiverse grassland); • Not from land with high carbon stock (e.g. wetlands); • Not from peatland as of 2008.
• Verification through mass balance system (Art. 7c).	• Verification and compliance for biofuels and bioliquids through mass balance system (Art. 18(1)).
GHG emission reduction targets and sustainability of biofuels	
• Life-cycle GHG emission reduction per unit of energy from fuel in road transport and non-road mobile machinery (Art. 7a): » 6% by 2020 (2% by 2014 and 4% by 2017); » 2% by 2020 (optional): other transport modes, carbon capture and storage; » 2% by 2020 (optional): clean development mechanism (CDM);	• Overall target of 10% of renewables in transport (Art. 3(4)).
• Only «sustainable» biofuels count (i.e. under Art. 7b).	• Only sustainable biofuels count (Art. 5(1)).

percent sub-target for second-generation of biofuels (double counted towards the 10 percent renewables in transport target); and fuel suppliers must report the estimated level of GHG emissions caused by ILUC to EU countries and the EC.[15]

The amended Article 3(4)(d) of the Renewable Energy Directive contains two exceptions to this quantitative limitation. Firstly, biofuels from an exhaustive list of feedstock, including straw, bio-waste, bagasse, nut shells etc., do not fall within the limit. Secondly, EU Member States can exclude crops that fall within the limitation from the scope of this limitation if all the sustainability criteria are met and the crops are grown on a specified type of land. The EU Member States have to adopt the respective implementing legislation by 2017.

The deal has been received with relief by the biodiesel industry, though it is far from being a perfect agreement, according to industry sources. The industry, represented by EBB, Fediol, and the European Oilseed Alliance, expressed the needs of long-term regulatory certainty particularly to sustain significant investment in Europe.[17]

The new law will enter into force at the end of October 2015. Member states are required to set national targets for the share of advanced biofuels within 18 months, and the legislation must be implemented within 24 months. The new cap on first-generation biofuels also restricts the European market for producers outside the EU (see Table 12, which illustrates that conventional biofuel demand is primarily met by domestic supply), and creates opportunities for external producers who want to supply the advanced ethanol market in Europe, for which trade can play a major role in the future.

A list of cellulosic ethanol projects and installed production capacities in Europe can be seen in Annex 2.

Limiting the role of first-generation biofuels in the future transport fuel mix, will require the EU to be prepared to supply sufficient amount of advanced biofuels to the market. Policy support for advanced biofuels needs

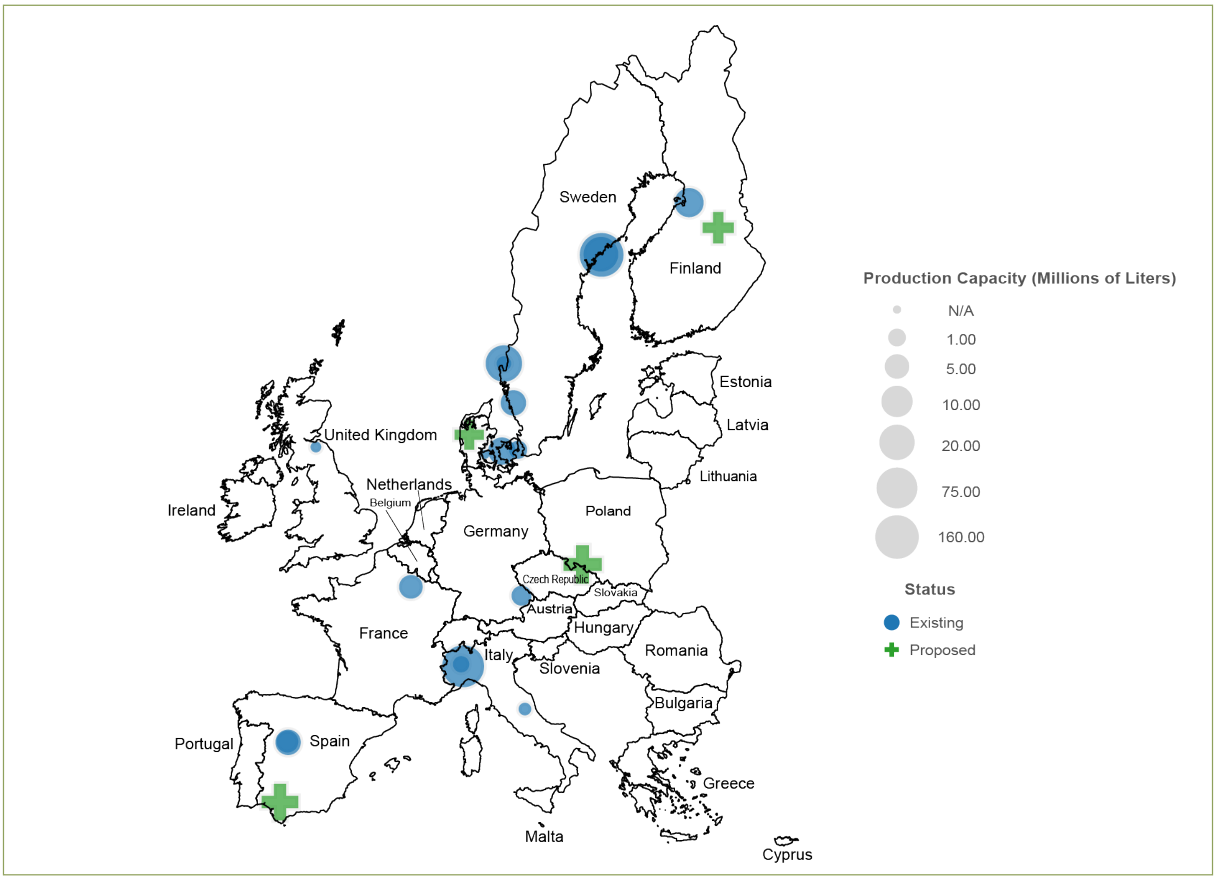
Table 12: Conventional biofuels in the EU*

	2013		2014**		2015**	
	Ethanol	Biodiesel	Ethanol	Biodiesel	Ethanol	Biodiesel
Production	5 541	11 676	5 900	12 661	5 900	12 560
Consumption	6 051	12 950	6 000	13 104	5 930	13 104
Imports	676	1 393	447	626	270	650
Exports	113	416	278	181	300	150
Net imports	563	977	169	445	-30	500
Net imports (%)***	9.30%	7.50%	2.80%	3.40%	-0.50%	3.80%

* In million litres, not considering fuel stocks.
** USDA (2015) forecasts.
*** % of total EU consumption.

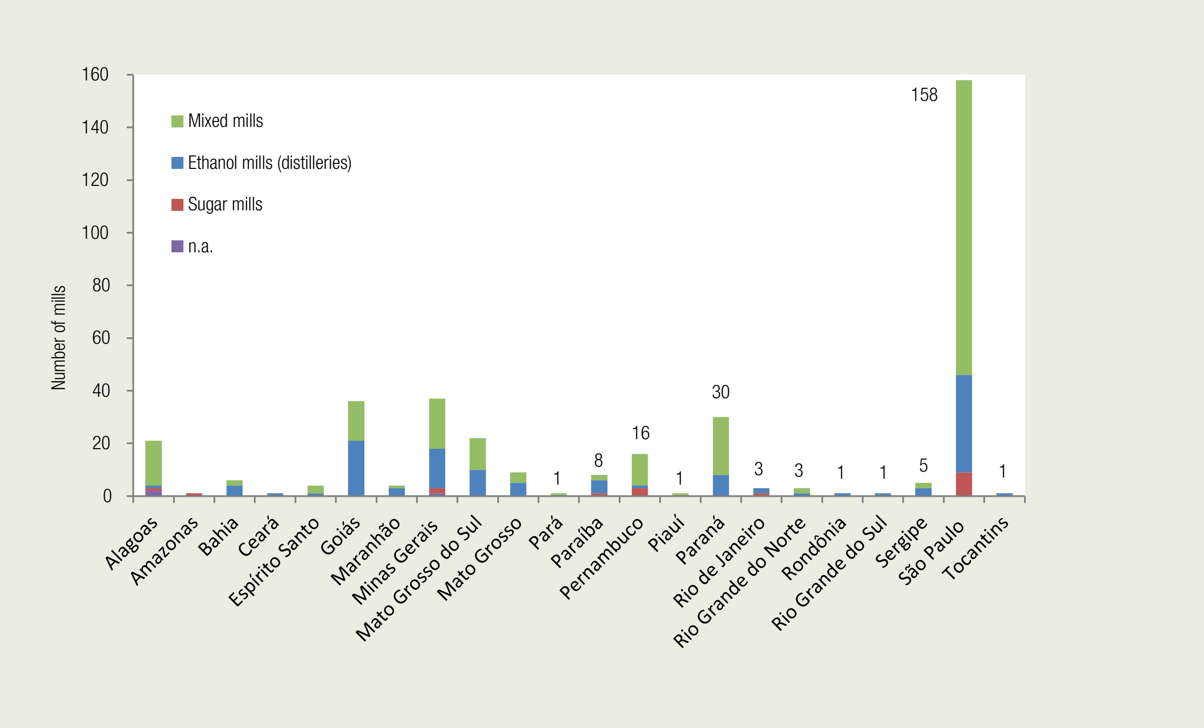
to be sustained by promoting biomass availability and technological deployment. The International Institute for Applied Systems Analysis (IIASA) reports on biomass potentials on a country level.[18] The potentially available land area for the cultivation of energy crops in the EU27 has been estimated to reach 47.8 Mha in 2030, and when combined with second-generation technology, the EU can potentially produce up to 13.5 EJ of biofuel.[19] Additionally, feedstock sourced from forestry and agricultural residues are estimated to provide between 11 EJ and 13 EJ, and surplus forest growth could provide approximately 35 EJ of biomass.[20]

Figure 13: Second-generation biofuel facilities in Europe



Sources: IEA task force 39; Ethanol Producer Magazine, 2015; Direct industry interviews. Credits: Duke Center for Sustainability & Commerce.

Figure 14: Distribution of ethanol mills in Brazil



Sources: Prepared by Alexandre Strapasson based on SAP-CANA (Brazilian Ministry of Agriculture).

In the case where imports are needed, particularly for agriculture and forestry biomass, the IEA has identified several potential countries that could become feedstock providers, including Brazil, China, India, Mexico, South Africa, Thailand, Tanzania, and Cameroon.[21] IRENA estimated the potential in REmap Renewable Energy Roadmap countries to amount to 48 EJ from energy crops and 13 EJ from forestry residues in countries that could potentially trade biomass for advanced biofuels production. However, developing countries such as Tanzania and Cameroon are lacking funds and technical support for second-generation biofuels; and investments remained limited primarily to the OECD countries, Brazil and China.

5.3 Brazil

Brazil has a large ethanol market and a well-developed market for first-generation ethanol and biodiesel in the country (Hira and Oliveira, 2009; UNCTAD, 2014). According to Figure 14, there are three main types of mills in Brazil - ethanol mills, sugar mills and mixed mills, which produce both outputs and represent the most common mill type.

The prevalence of mixed mills in Figure 14 highlights the business preference to spread risk (Pacini and Strapasson, 2012). Markets of sugar, ethanol and bioelectricity have been offering hedging options for producers over the last decades. Cellulosic fuels and biomaterials offer further options for product diversification, which opens new export and domestic markets. The second-generation biofuel industry in Brazil has had a tendency to develop based on existing infrastructure and feedstock logistics, which are in place for its established first-generation industry.

The biofuel mandates established by the Energy Independency and Security Act (EISA) in the US in 2007, the Renewable Energy Directive (RED) published by the EC in 2008 and the Low Carbon Fuel Standard (LCFS) created in 2007 in the State of California, have played an important role for the development of second-generation biofuels in Brazil by driving demand. Brazil has not set internal goals for the consumption of second-generation biofuels, but has introduced some incentives to foster R&D and the start of production.

According to Milanez et al. (2015), the Brazilian

Development Bank (BNDES) and the Brazilian Innovation Agency (Finep) launched the Joint Plan for the Industrial Technological Innovation of the Energy and Chemical Sugarcane-based Industries (PAISS) in 2011, which were directed towards companies wishing to invest in R&D. Similarly, the São Paulo State Research Foundation (Fapesp) launched the Bioenergy Research Program directed towards academic institutions and joint research projects between the private sector and Academia.

The PAISS programme played an important role in the construction of one pilot and two commercial second generation ethanol plants, which total 140 million litres production capacity and commenced production in the second half of 2014. The programme has provided over 2 billion Reais (US$ 570 million in 2015) to 35 projects within three different research areas: second generation ethanol, new products made from sugarcane through biotechnology and gasification.

Although the incentives of the American and European markets were important to attract investments in cellulosic ethanol, the stagnation of industrial and agricultural yields of first-generation ethanol in Brazil helped to influence investments decisions in new technologies.

Table 13: Average yields and growth

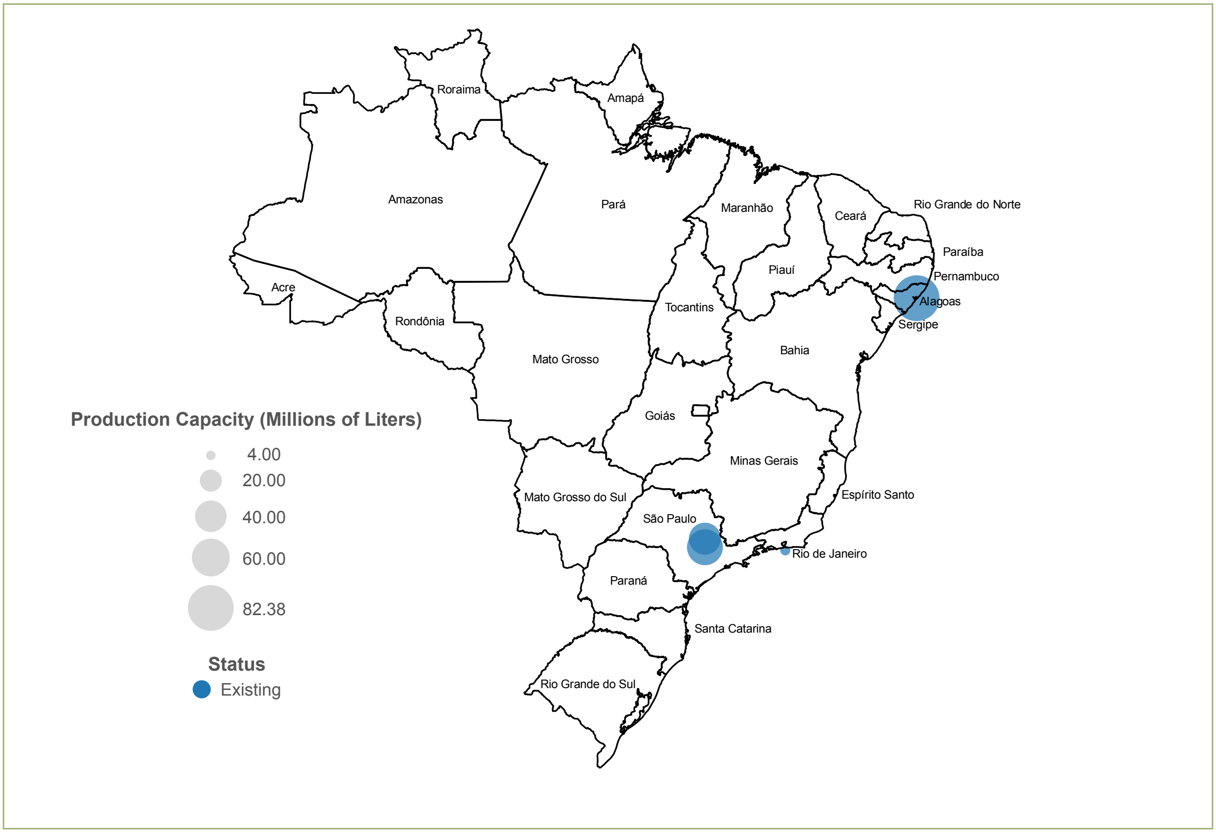
Period	kg TRS/ha	Growth (%)
1975-1984	6 351	-
1985-1994	8 299	30.7
1995-2004	9 810	18.2
2005-2012	10 509	7.1

Source: Nyko et al. (2013).

According to Nyko et al. (2013), the peak in sugarcane yields was observed in 2007 reaching 11,200 kg of Total Recovery Sugars per hectare (TRS/ha). During the following years, a combination of adverse weather, reduction of cane field renewal and growth in mechanized planting and harvesting contributed to the decrease of yields.

Additionally, there is a clear gap between the actual and

Figure 15: Second-generation biofuel facilities in Brazil



Sources: IEA task force 39; Ethanol Producer Magazine, 2015; Direct industry interviews.
Credits: Duke Center for Sustainability & Commerce.

potential sugarcane yield, which is estimated at 381 tons/ha but averaged only 70.5 tons/ha in 2014/15 (Conab, 2015). Nonetheless, other crops such as soybeans, corn and wheat experienced a much greater increase in yield than sugarcane. For example, while sugarcane yields increase by 46 percent from 1977-78 to 2011-12, wheat yields increased by 318 percent in the same period in Brazil (Nyko et al., 2013).

CTBE, the Brazilian Bioethanol Science and Technology Lab, simulated 14 scenarios of second-generation ethanol production using different technologies that would achieve higher yields in the medium and long term. Compared to the baseline for a first-generation sugar and ethanol facility, the production of ethanol per ton of cane can grow from 53.6 to 124.6 litres when processes are improved and C5 sugars are successfully fermented together with C6 and all synergies with first-generation ethanol production are captured. CTBE estimated production costs for second generation ethanol to be competitive with oil prices in the short-term at US$ 128 per barrel and in the long-term at US$ 44 per barrel (Milanez et al., 2015).

Milanez et al. (2015) estimated the prospects for second-generation ethanol production in Brazil until 2025. The forecasts take into account a scenario in which public policies are implemented in order to incentivize the production and consumption of 2G ethanol (see table 14). Oil prices were assumed to remain above US$ 60 per barrel.

Table 14: Production potential in Brazil (billion litres) by type of investment

Type of investment	Production potential (billion litres)		
	2016-2020	2021-2025	Total
Retrofit existing mills to 2G ethanol	2.50	2.50	5.00
Expansion of mills with 2G ethanol	0.75	0.75	1.50
New mills with 2G ethanol	0.00	3.50	3.50
Total	3.25	6.75	10.00

Source: BNDES.

5.3.1 Retrofitting existing sugarcane mills

An analysis of existing sugarcane mills in Brazil shows that 159 mills exported electric power in 2014. Together, those plants represented a milling capacity of 393 million tons of sugarcane per year, resulting in an average crushing capacity of 2.5 million tons per mill (NovaCana, 2015; IDEA, 2014).

According to BNDES (2015), part of those sugarcane mills could be optimized to generate large quantities of surplus lignocellulosic material, which could be routed towards the production of second-generation ethanol. According to Milanez al. (2015), mills with steam consumption of approximately 360 kg/ton of sugarcane, harvesting 50 percent of sugarcane trash in 90 percent of the harvested area (considering mechanized harvested area only), could result in 105.6 kg of dry lignocelulosic material per ton of sugarcane. Still according to the study of Milanez et al. (2015), a single mill with second-generation ethanol processes and using existing technology is capable of producing 216.9 litres of 2G ethanol per ton of dry lignocellulosic material. This means that 22.9 litres of 2G ethanol could be produced for every ton of sugarcane harvested, according to BNDES calculations.

Importantly, some of the existing sugarcane mills in Brazil can optimize their production more easily to generate lignocellulosic material. This is the case for mills that have outdated or inefficient equipment, which, in that case, could enable a rapid and cost-efficient route to 2G bioethanol through relatively low capex retrofits. Therefore, considering plants with milling capacity equal or greater than 2 million tons of cane per year and which exported at least 20 kWh per ton of cane, 81 mills would still meet these criteria. Altogether, those mills represent a combined milling capacity of 275 million tons of cane per year, which annually averages at 3.4 million tons of cane per plant. In this scenario whereby 80 percent of the mills with the required characteristics begin to adopt near-term technologies to produce 2G ethanol, it would be possible to annually produce 5 billion litres of 2G ethanol until 2025. Such retrofit arrangements should fast-track 2G production and increase ethanol mill productivity (based on equipment upgrade) without compromising the installed capacity for 1G production.

5.3.2 Expansion and construction of new mills

According to BNDES (2015), the existing sugarcane industry in Brazil could expand its annual milling capacity by up to 100 million tons of cane. Considering that 80 percent of this potential is actually viable, it would be possible to add up to 1.5 billion litres of 2G ethanol per year in Brazil up to 2025.

Given Brazil's interest in reducing gasoline imports, new investments are expected to take place in ethanol mills in the mid-term. From 2020 onwards, a greater use of sugarcane varieties adapted for energy production (*cana-energia*) is expected that can increase the ethanol yield to nearly 19,000 litres per hectare.

In this context, and considering the average size of new mills (approximately 40,000 hectares), BNDES suggest that it is plausible to expect the construction of 10 new ethanol mills per year from 2020 onwards, with an annual capacity increase of 760 million litres, including a 350 million 2G ethanol increase. In this scenario, it would be possible to add an additional 3.5 billion litres of 2G ethanol each year through the construction of new sugarcane mills.

5.4 Africa

Despite high energy needs and a large development potential[23], the biofuels sector in Africa has not experienced significant growth lasting recent years. Due to a limited production size and the absence of a comprehensive production record, providing a quantified estimate of the second-generation biofuels market proves challenging. Nevertheless, by analyzing the trends of the overall African biofuels market and by studying the emerging and current second-generation production options currently explored in Africa, it is possible to create an overview of the sector.

5.4.1 A limited biofuels market

It is estimated that Africa only accounted for less than 0.04 percent[24] of global biofuel production in 2012, and virtually the entire African market consists of first-generation biofuels. This global market share has also been declining for two years due to a decrease in African output. The difficulties of African biofuels production can be attributed to the abandonment of large-scale projects, several of them involving Jatropha, and controversies over land grabbing allegations.

In this context, the development of second-generation biofuels faces economic and technical constrains[25] that go beyond those encountered by first-generation biofuels. According to van Zyl et al. (2011), the cost of production of a second generation biofuel is dominated by investment costs, which places second-generation technologies at an even greater disadvantage in Africa.

In addition, methods for lignocellulose pre-treatment/fractionation while available might not be optimized for local substrates and novel African bioenergy crops.

Figure 16 below illustrates the decline in the African biofuels production

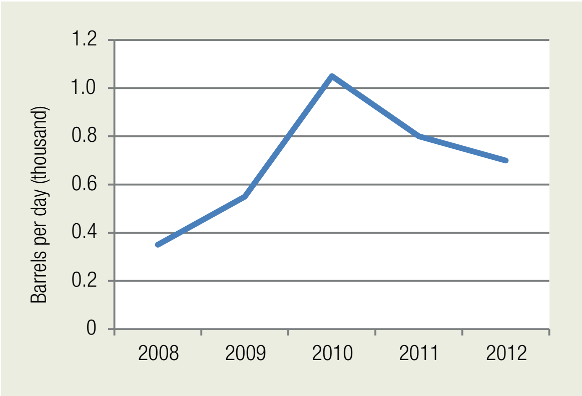
Available data shows that Eastern and Southern African countries are the main biofuel producers of the continent for both first and second-generation products. The following table shows a breakdown by country of overall African output. Two main observations can be made on these figures. Firstly, a significant level of production was only recorded for 8 countries. This can be due to the limitations of the production tracking system or to the small size of the industry. Secondly, for 5 of these 8 countries, the production has remained stable for four years or more. Only the South African production recorded 3 consecutive years of growth. South Africa's emergence as a future major producer at the African level is also confirmed by qualitative data collected on second-generation biofuels.

Besides these current production trends, long-term projections also point towards a limited growth of the African biofuels market. As illustrated in the figure below from the IEA's African Energy Outlook, biofuels are expected to play a marginal role in the African energy mix until at least 2025.

5.4.2 Emergence of small-scale second-generation biofuel production projects

Despite the limited scale of their production, several African countries have been home to innovating non-food crop based biofuels projects. As previously noted,

Figure 16: Biofuel production in Africa



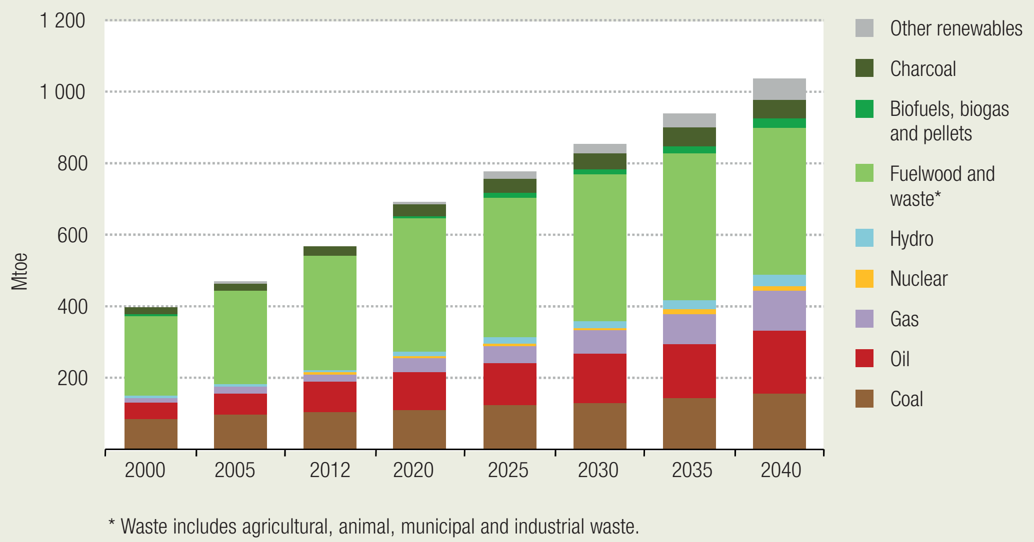
Source: EIA.

Table 15: African biofuels production (thousand barrels per day)

	2008	2009	2010	2011	2012
Ethiopia	0.10	0.10	0.10	0.10	0.10
Malawi	0.20	0.20	0.20	0.20	0.20
Mozambique	0.00	0.02	0.02	0.02	0.02
Rwanda	0.00	0.01	0.01	0.01	0.01
South Africa	0.005	0.04	0.06	0.13	0.13
Sudan and South Sudan	0.00	0.10	0.50	0.20	0.20
Tanzania	0.00	0.01	0.01	0.01	0.01
Zimbabwe	0.04	0.06	0.12	0.12	0.02
Total	0.35	0.54	1.02	0.79	0.69

Source: EIA.[26]

Figure 17: Primary energy demand in sub-Saharan Africa by fuel



Sources: African Energy Outlook, new policies scenario.[27]

these initiatives have predominantly taken place in Eastern and Southern Africa even though West Africa has also been the stage of promising projects.

The production and trade of second-generation biofuels in Africa is characterized by its limited scale and the existence of promising market niches such as cooking fuel supply. The current low price of oil, difficulties encountered in the implementation of earlier projects, as well as the higher level of investment required for the development of second generation biofuel ventures do not point towards a large-scale development of the sector in the near term.

Two main types of second-generation biofuel projects can be found on the continent - the transport industry and domestic uses such as cooking. In addition, the use of bagasse to generate electricity could be regarded as an additional advanced biofuel-related practice, which has increased in Africa. These are discussed below.

Biofuels in African Transportation

Transportation is one of the largest markets for African biofuels with countries such as Angola, Ethiopia, Kenya, Malawi, Mozambique, South Africa and Sudan having all introduced blending mandates[28]. Whereas first generation biofuels have been mainly used to meet this demand, several second-generation biofuels projects have been developed in recent years.

Project Solaris currently implemented in South Africa at the initiative of Boeing, South African airways and other partners is an example of an innovative project to promote the development of second-generation biofuels in the African transport sector. The project aims to produce bio-jet fuel using Solaris, an energy rich and nicotine free variety of tobacco. As of December 2014, 50 hectares of Solaris had been planted in the Limpopo province and blended fuel could be used by the airline as early as in 2017. [29]

Still in South Africa, as part of the implementation of the national Biofuels Industrial Strategy, 8 licenses were issued for the total annual production of 1,362.2 million litres of biofuels (bio-ethanol and bio-diesel). One of these licenses covers the annual production of 12 million litres of biodiesel using waste vegetable oil. [30] Even though the quantity of biodiesel is relatively modest (around 0.88 percent of the planned production) the realization of the proposed investment could be regarded as setting an important precedent in the production of second-generation biofuels for the transportation sector in Africa.

Cooking and other household uses

The production of non-food based biofuels for domestic purposes such as cooking is among the earliest cases of advanced biomass use in Africa. While not strictly considered an advanced biofuel, biogas merits some consideration in the African context due to the recent progress made.

The technology for the production of domestic biogas, using manure as a principal input material, was introduced in Ethiopia during the second half of the last century. Since 2009, the country has been implementing a National Biogas Programme (NBP), which has resulted in the installation of almost 8,000 family-sized domestic biogas plants, primarily in rural communities, between 2010 and 2015.[31] According to the Africa Biogas Partnership Programme (ABPP) a second phase is currently being implemented and has already led to the installation of 1,762 domestic plants in 2014.[32]

Similar efforts in supporting the deployment of domestic biogas facilities were undertaken in Burkina Faso, Kenya, Uganda and Tanzania (where sisal is also used to produce biogas) with almost 20,500 domestic biogas plants installed in these 4 countries in total.[33]

Another example of improved biomass usage for domestic purposes is the cookstove fuel produced by Green Energy Biofuels, a private sector company recognized by the UN Foundation-backed Global Alliance for Clean Cookstoves, which uses fuel based on saw dust and water hyacinths.

According to the available data,[34] the company claims 200,000 users of its ecofriendly cookstoves and renewable biofuel cooking gel in Nigeria and Ghana. A total of 800,000 litres of cooking gel is also reported to have been sold and efforts are underway to increase the production capacity of cooking gel to 22 million of litres per annum in order to supply the West African market.

Electricity Generation based on sugarcane bagasse

The transformation of bagasse into electricity also has a long history in Africa, and has the potential to serve as a basis for second-generation biofuel production. Electricity generation is typically performed by sugar cane processing plants to convert some of the by-products into energy.

As with the overall biofuel production, only limited data is available on the use of bagasse for electricity generation purposes. Nevertheless, existing data suggests that the volume of bagasse used to generate electricity is slightly decreasing. The following table shows for instance that in Swaziland and Senegal, the two largest bagasse users among the surveyed countries, registered respectively a 17 percent and a 5 percent decline in the quantity of bagasse used for electricity generation.

Table 16: Transformation of Bagasse in electricity, CHP and heat plants[35] (in thousands metric tons)

	2008	2009	2010	2011	2012
Mauritius	326	342	342	342	359
Senegal	1 301	1 136	1 140	1 119	1 078
Swaziland	1 846	1 777	1 750	1 843	1 762
Uganda	21	25	25	24	27
Tanzania			42	58	44

6. STATUS OF ALGAE-BASED BIOFUELS

Algae have been considered the most promising renewable fuel feedstock (Jones and Mayfield, 2012). Biofuels made from Algae have been refered to as third-generation biofuels in literature, although this definition is not ubiquitous (Singh et al., 2011). Since 1970s its usage as a biofuel feedstock is being studied in the US, but all attempts failed to deliver enough support to maintain the initiatives at that time and other green feedstock and technologies replaced it. Recent concerns about the resources limitation, land use and climate change led to research into algae biomass being resumed. Currently, the production of algae biomass is not cost-effective due to numerous technological barriers that must be overcome in order to better exploit the biomass potential.

Algae are a diverse group of primarily aquatic organisms ranging in size from the microscopic to large seaweeds (US DOE, 2015) and can be considered an interesting biofuel feedstock option due to their fast growth, net zero emission balance and the high lipid production capacity (Alam et al., 2012). The harvesting of algae does not compete with human or animal food crops and it can grow on non-arable land, as well as in freshwater, brackish, salt water or wastewater. Its carbon fixation capacity is much higher than other land grown plants, with harvesting cycles of less than ten days (BIOFAT, 2011).

Among all feedstock used for the production of advanced biofuels (corn stover, corn cob, bagasse, straw, wood waste, cellulose, mixed biomass, hardwood, forest residue, animal waste and algae), it is theoretically possible for most second-generation biofuels to be produced from algae due to its very high yield-per-area (Allied Research, 2014). However, few developing countries are investing in new ventures based on algae and generally the plants developed are still on a demonstration-scale or did not make commercialization viable. Consequently, the global market is in its emerging stage and companies are working on establishing pilot plants and R&D activities.

Since 2009, the 100,000 known strains of microalgae in the world were being studied by at least 100 companies with interest in investing in the promising potential of this biomass according to a recently released Oilgae comprehensive report about the sector. It estimates that until 2012 there were 300 companies directly involved in producing fuels from algae (Oilgae, 2015). The US DOE recently (July 2015) offered US$ 18 million in funding to reduce the modelled price of algae-based biofuels to less than US$ 5 per gallon by 2019, which reveals the importance of the research and development of valuable biofuels from algae for energy security and the future of liquid fuels. Other global regions have their own initiatives, which are summarized below.

6.1 Europe

The European Biodiesel Board represents the major biodiesel producers in the EU and promotes the adoption of algae-based biodiesel. Through its 7th Framework Program, the EC is involved in three large-scale industry-led projects aimed at demonstrating the production of algal biofuels, including cultivation and production, oil extraction, and biofuel production and testing in transportation applications. By early 2011, these projects had received a total contribution from the EC of € 20 million (approximately around US$ 27 million), with a total cost of € 31 million (US$ 42 million) (BIOFAT, 2011).

The BIOFAT programme is one of the three projects above mentioned, and integrates the entire value chain of the algae process from optimized growth, starch and oil accumulation, to downstream processing including biofuel production (BIOFAT, 2011). Ten partners from seven different countries have joined the € 10 million (US$ 13.5 million) project with the intention of introducing the concept of algo-refinery, which is a facility that can produce high-value co-products in addition to biofuels. Another initiative, EnAlgae received funding to develop nine pilot facilities in North West Europe. EnAlgae is a four-year Strategic Initiative of the INTERREG IVB North West Europe programme, which funds 50 percent of the project (€ 7.3 million or US$ 10 million).

The AUFWIND project, in Germany, was launched in 2013 and involves twelve partners from research and industry that are developing microalgae as a basis for the production of biokerosene. Key questions addressed are the economic and ecological feasibility of the process. The Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) is funding the project with € 5.75 million of finance through its project management organization FNR (Fachagentur Nachwachsende Rohstoffe). The total funding for the project amounts to € 7.4 million.

6.2 Americas

Solazyme Bunge, located in Brazil, produces biodiesel, renewable diesel and jet fuel with sugarcane and algae. The production at the Brazil plant is capable of annually producing 88 million litres (100,000 metric tons) of renewable oils. The plant is co-located with Bunge sugarcane mill, and it has received a US$ 120 million loan from BNDES. In 2012, Solazyme Bunge announced their intention to expand production capacity from 100,000 metric tons to 300,000 metric tons in 2016 and that the portfolio of oils will broaden to include food oils for sale in Brazil.

In 2013, a US$ 19 million demonstration algae biorefinery in Canada was announced. The Algal Carbon Conversion Pilot Project uses carbon dioxide from oil sand facilities and derives from a partnership between the National Research Council, Canadian Natural Resources Limited and Pond Biofuels. The Bioenergy Technologies Office (BETO) in the US supports the development of technologies to sustainably grow and convert algae into advanced biofuels and bioproducts. It provides cost-shared funding to partners, such as Sapphire Energy Inc. (demonstration scale), Algenol Biofuels Inc. (pilot scale), Solazyme Inc. (pilot scale), and BioProcess Algae (pilot scale).

The National Alliance for Advanced Biofuels and Bioproducts consortium, from 2010 to 2013, developed technologies with the potential to reduce the cost of algae-based biocrude oil from US$ 63.4 to US$ 1.98 per litre. Two hundred researchers and thirty-nine institutional partners were involved and the total public investment achieved $48.6 million (NAABB, 2014). The project discovered a new high-performing strain (Chlorella sp. DOE1412), screened more than 2,000 algal strains, improved cultivation methods and demonstrated three innovative harvesting technologies at larger scale.

6.3 Asia

Algenol and Reliance Industries Ltd., an Indian oil company, built a demonstration module near the world's largest refinery – the Reliance Jamnagar, with the intention to integrate refinery operations with Algenol's platform. ENN, a Chinese biofuel producer, signed a partnership with Airbus and the company EDAS to jointly develop and test aviation fuel made from algae (OILGAE, 2015). The Dubai-based Lootah Biofuels signed a contract with AlgaOil Ltd. to develop conjointly raw materials from algae.

In Japan, the Algae Biomass Energy System Development Research Center was established at the University of Tsukuba in 2015 with the objective of finding practical uses for algae-derived oil and to create a new algae industry. South Korean energy officials confirmed that the country would invest from 2009 to 2019 to create 86,000 acres of offshore seaweed forests that will annually produce more than 300 million gallons of ethanol by 2020.

6.4 Africa

InnoVenton, based in South Africa, created a blend called Coalgae, which uses algae biomass to convert waste coal into a high quality coal that can be readily processed into biofuel (SAI, 2015). The MED-ALGAE Project is a €2 million project that began in 2014 and runs for 26 months with the objective to establish a biodiesel production pilot in each of the five participating countries (Lebanon, Egypt, Malta, Cyprus and Italy) (EBTP, 2015).

6.5 Oceania

Algae.Tec is an Australian/US based company with projects in Australia, US, Sri Lanka, Germany and India. The Sri Lanka facility will eventually produce 31 million litres of oil for biofuel production. This company produces algal oil and partners with refineries to produce a variety of renewable fuel products, such as biodiesel and jet fuel. In 2014, Muradel, an Australian company, launched a AU$ 10.7 million, 30,000 litre/annum plant to demonstrate its Green2Black (algae to crude oil) technology at industrial scale, which represents the first step towards an 80 million litre commercial plant (EBTP, 2015). Aurora Algae, in 2013, announced it had constructed a demonstration algae cultivation site in Western Australia.

7. SECOND-GENERATION BIOFUELS: SUSTAINABILITY ISSUES

Second-generation biofuels are novel and innovative, but have their own sustainability impacts. While they are typically non-traditional commodities, higher yielding and often non-food crops that do not compete with food markets, they may not fit neatly into traditional biofuel definitions.

Nonetheless, dangers with second-generation feedstocks can include highly invasive crops that could be higher yielding than first-generation feedstocks, but can still cause issues or damage to ecosystems.

Second-generation biofuels from agricultural wastes can encourage the removal of excess crop residues from the land. For example, if all crop residues can be converted to cellulosic ethanol and removal is excessive, potential impacts such as damage to soil quality and waterways was occur. Schemes such as the Roundtable on Sustainable Biomaterials addresses this risk by requiring that the usage of lignocellulosic material does not occur at the expense of long-term soil stability and organic matter content.

Second-generation biofuels that involve waste taken from processes, such as methane from landfills or converting waste from fossil fuel derived processes, can also be have sustainability issues (Mohr and Raman, 2013). Consequently, sustainability standards are vital in order to provide clarity about their true impacts and to what extent they are better than fossil fuels. Sustainability standards can also provide specific requirements to cover the risks of negative impacts related to removing residues from agriculture/forest areas.

Biofuels produced from wastes and residues offer a number of advantages. In the food *vs* fuel and iLUC debates, policymakers often favour these materials over biofuels made from virgin oils and sugars. They also offer better GHG savings compared with virgin materials, as they do not require land cultivation and the use of energy-intensive inputs. However, it is important to ensure that only genuine wastes and residues enter the supply chain. The most common of these materials used for biofuel production are used cooking oil (UCO) and tallow.

Sustainability schemes should be rigorous, but with an element of flexibility in their implementation, to allow waste material originating from a wide range of producers to be eligible. The upstream verification needs to be economically feasible to encourage their uptake in the biofuels sector. The procedure is summarized in the Flow Diagram below.

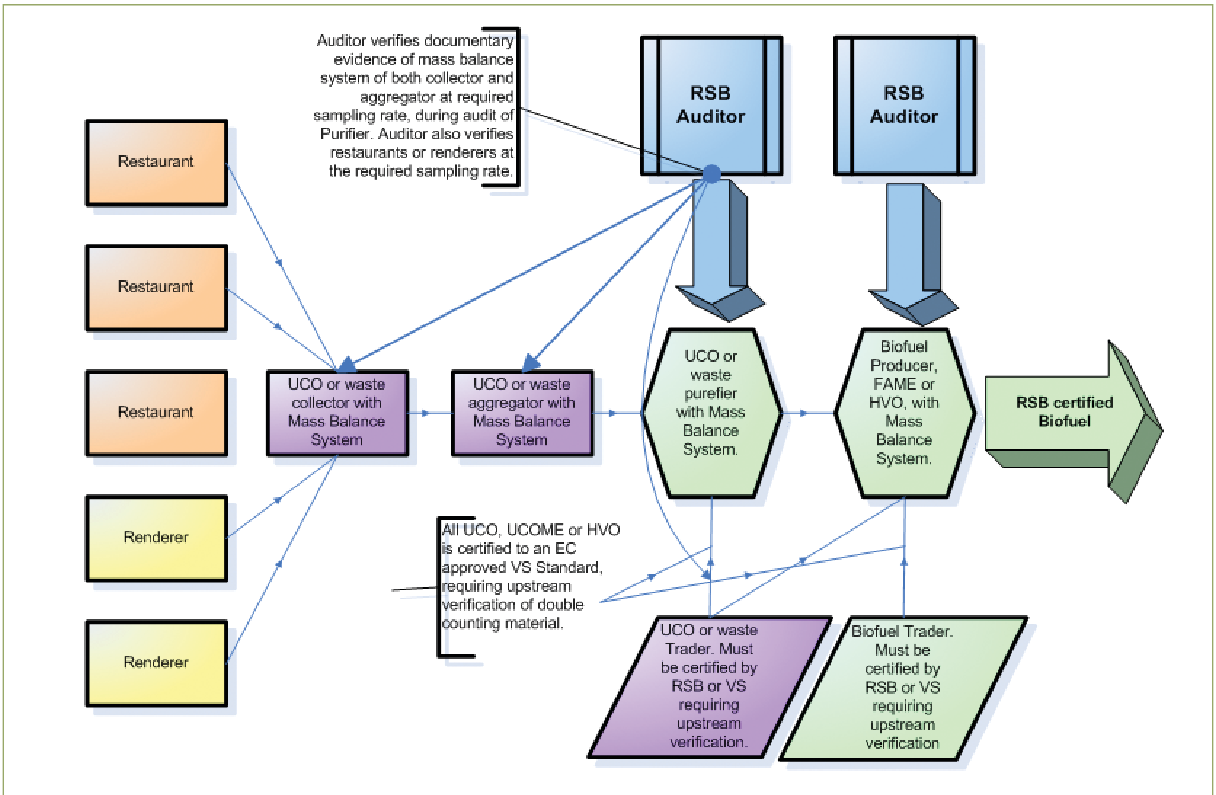
8. PROMOTING SECOND-GENERATION BIOFUELS: WTO LAW IMPLICATIONS

8.1 Setting the scene: promoting international trade in sustainable biofuels

International trade connecting domestic and regional biofuel markets is of key importance to allow countries to achieve their renewable energy and fuel blending targets as a part of climate change mitigation and adaptation policies, as well as diversification of the energy mix. While biofuel markets have been largely liberalized, a number of tariff and non-tariff measures, including subsidies and various certification requirements, as outlined above, continue to restrict market access for biofuels in a number of countries (UNCTAD, 2014).

By promoting biofuel production, governments pursue several objectives, including climate change mitigation and the reduction of GHG emissions, and the diversification of energy supply, but also economic and social objectives, including the development of new industry sectors, employment, etc. Governments choose different ways of balancing these various interests, however this should not be done by resorting to protectionist measures that lead to market fragmentation (UNCTAD, 2008). Introduction of sustainability criteria (so far existing only in the EU and the US), could play an important role to avoid undesirable externalities of increased biofuel production (e.g. destruction of carbon sinks, damage to biodiversity, violation of human rights). At the same time, as mentioned in Chapter 4, an increasing

Figure 18: Flow diagram example of the certification of biofuels from wastes and non-agricultural residues



Source: RSB Standard.

number of concerns are being raised with respect to the level of sustainability that can be achieved by the first-generation biofuels and consequently the need to treat first-generation and second-generation biofuels differently (UNCTAD, 2008).

Taking into consideration these most recent developments, it appears important to understand what policy space governments have to balance various public policy objectives in the biofuels sector in light of their WTO obligations. The following sub-section briefly addresses the most recent policy employed by the EU to promote second-generation biofuels from the perspective of its potential compatibility with WTO law.

8.2 Recent EU policies to promote second-generation biofuels and WTO law

The EU biofuels policy, including the 2009 sustainability criteria, from its inception raised concerns with respect to their compatibility with WTO law (Pacini and Strapasson, 2012). While the criteria apply equally to biofuels produced inside and outside the EU, some non-EU countries producing certain types of biofuels may find themselves more affected by these requirements than the others. A number of studies addressed the WTO compatibility of the sustainability criteria and default values of life-cycle GHG emissions of various types of biofuels (Swinbank and Carsten, 2013; Switzer and McMahon, 2011; Kulovesi, et al., 2011; Mitchell and Tran, 2010; Lendle and Schaus, 2010). In recent years, the EU biofuel policy led to several dispute settlement proceedings in the WTO. The proposal of the EC to include iLUC criteria and to establish a cap for first-generation iLUC-intensive biofuels with some exceptions was also criticized, as it would potentially deteriorate the inconsistency of the EU biofuels regime with WTO law (Laurenza, 2013; Erixon, 2013; Ros, et al., 2010).

Whereas WTO law does not specifically deal with the energy sector or biofuels, it establishes basic rules and principles for international trade in goods, which encompasses biofuels. The amended Directives therefore fall under the scope of the General Agreement on Trade in Goods (GATT) and potentially under the Agreement on Technical Barriers to Trade (TBT Agreement). As in many EU Member States, iLUC and sustainability criteria are linked to financial support schemes, which means that affected countries would potentially challenge the EU policy also under the WTO law subsidies disciplines. The latter would require more specific information about the exact national implementation of the revised Directives in terms of the link between the iLUC criteria and the financial support granted. For the reasons of insufficient factual information this aspect is not addressed in this report.

8.3 Compatibility of the new iLUC requirements for biofuels with the GATT

WTO Members have a key obligation to treat the same kind of competing foreign and domestic products in a non-discriminatory manner. According to the most-favoured nation (MFN) obligation the WTO Member has to accord automatically and unconditionally to all other countries – members to the WTO any advantage that was accorded to any other country (Article I:1 GATT). According to the national treatment obligation the WTO Member should not treat foreign products less favourably (e.g. through requirements affecting internal sale, transportation etc.) than its 'like' domestic products (Article III:4 GATT).

In order to establish a discriminatory treatment under both obligations, the biofuels affected by the revised Directives have to be 'like'. According to the well-established four-step analysis of 'likeness', the biofuels in question would be compared with respect to their (i) properties, nature and quality; (ii) end-uses; (iii) consumer tastes and habits; and (iv) the tariff classification (Appellate Body Report, 2001). Similarly to the differentiation of biofuels based on sustainability criteria, the iLUC criteria take into consideration the factor of GHG emissions due to indirect land use change. Here the differentiation between biofuels occurs on two levels. Firstly, the revised Directives differentiate between iLUC-intensive and advanced non-iLUC biofuels (e.g. sugar cane ethanol vs. waste wood ethanol). Secondly, due to the existence of the seven percent EU-wide cap, the differentiation occurs even between those biofuels that are accepted within the threshold and those exceeding it. As the factor of GHG emissions refers to the life-cycle emissions of biofuels and not the emissions caused through their consumption, this factor is not decisive for the physical properties criterion, unless there are proven differences in chemical composition between iLUC-intensive and non-iLUC biofuels. There is a high probability that the iLUC-intensive and non-iLUC biofuels in a specific case would be found 'like', as the iLUC criteria are based on the non-product related process and production methods (npr PPMs). The 'likeness' of iLUC-intensive biofuels based on a quantitative threshold is beyond any doubt (Erixon, 2013).

The revised Renewable Energy and Fuel Quality Directives set the same iLUC requirements for biofuels produced in the EU and abroad. However, as mentioned, their criteria can predominantly only affect some countries due to the list of iLUC-intensive biofuels covered by the cap and the estimated iLUC GHG emissions. While, there is no import ban on the iLUC-intensive biofuels in the EU, the whole biofuel policy framework in the EU and its Member States discourages the use of non-compliant biofuels. Therefore, a WTO panel would have to establish whether the foreign biofuel industries are treated less favourably through the new regime (e.g. predominantly the EU iLUC-intensive biofuels would come under the seven percent threshold or the affected biofuels are mainly produced in some countries abroad). In such a case, even if there is no *de jure* discrimination, a *de facto* discrimination could potentially be still claimed by the affected states exporting biofuels to the EU.

Besides potential *de facto* discrimination, affected WTO Members could also challenge the iLUC requirements as a quantitative restriction within the meaning of Article XI:1 GATT, as the simultaneous application of Articles III:4 and XI:1 GATT is not excluded. While the revised Directives do not explicitly set any quantitative restrictions on the importation of iLUC-intensive biofuels, the new regime might still result in the distortion of competitive opportunities of predominantly foreign producers of biofuels. In such a case a complaining WTO Member would have to provide evidence of the actual trade impact (lower level of imports/exports) of a measure and prove that this effect is caused by the Directives and not by other reasons.Despite the potential violation of non-discrimination obligations under Articles I:1 and III:4 GATT and of prohibition of quantitative restrictions under Article XI:1 GATT, the EU could potentially invoke the general exceptions clause of Article XX GATT to justify the revised biofuel regime. The EU revised biofuel regime would have to fall within one of the public policy objectives listed in paragraphs (a) – (j) of Article XX and then also meet the requirements of the introductory paragraph also known as the 'chapeau'. According to the wording of the Proposal, the revised Directives set the long-term sustainability objectives, which encompass the prevention of GHG emissions from indirect land use change, the prevention of damage to biodiversity due to indirect land use change and the promotion of food and nutritional security. Environment-related objectives could fall within the scope of broader policy goals of the protection of human and animal life and health under Article XX(b) or preservation of exhaustible natural resources under Article XX(g) GATT. The food and nutritional security concerns could also be subsumed under the purview of Article XX(a) GATT, as a matter of public morals.

Justification of the revised Directives under Article XX GATT depends to a large extent on the available scientific evidence on the effectiveness of the iLUC criteria for the achievement of the objectives pursued. According to the EC, food price volatility has often been linked to biofuel production, however, since 2008 there is no common trend between increasing biofuel production and rising food prices (European Commission, 2015). Therefore, without scientific evidence to the contrary, it might be difficult to show how iLUC requirements promote food security. With respect to iLUC and GHG emissions, the EC itself recognizes that there might be exceptions that should be reflected in various certification schemes to be developed in future. Given the uncertainty about the effects of iLUC and the variability of iLUC related emissions depending on time and location of land use change, such certification schemes should be relatively flexible to allocate such differences.

One of the key questions under Article XX GATT relates to the existence of a reasonably available and less trade restrictive measure that would contribute to the achievement of the set goal to the same extent as the original measure. This proportionality test is built into the 'necessity' requirements of Article XX(b) GATT. To this end the EU would have to demonstrate why exactly the threshold of seven percent is necessary to ensure the preservation of biodiversity and how it would promote food and nutritional security. Implementation of a comprehensive methodology that considers both direct and indirect land use change GHG emissions and thus paying due regard to possible efficiency measures might be an option without setting a cap. Based on this methodology various certification schemes can be developed.

Finally, under the chapeau of Article XX GATT, the application of the revised Directives (and the implementing national legislation) would be tested. The primary question here would be whether they cause an arbitrary and unjustifiable discrimination or a disguised restriction on trade. Much will depend on the exact implementation of the measure (e.g. how the access to the seven percent group will be allocated, and when and which emission reduction efficiency certification schemes would be developed to possibly bypass the quantitative threshold). It should be noted, that at least under the chapeau analysis, the inclusion of iLUC GHG emissions (but not the cap) might make the whole sustainability scheme more coherent with respect to the objectives pursued, and consequently more resistant to challenges.

8.4 Compatibility of the iLUC criteria with the TBT Agreement

The TBT Agreement applies to technical regulations, i.e. to 'documents which lay down product characteristics or their related processes and production methods including the applicable administrative provisions, with which compliance is mandatory'. The revised Directives constitute documents, with which compliance is mandatory. However, they introduce the iLUC life-cycle GHG emissions criteria, which are not necessarily reflected in the physical properties of biofuels. The question of the applicability of the TBT Agreement to the regulations dealing with the npr-PPMs so far has not been dealt with by the WTO adjudicating bodies and remains a subject of academic discussions.

Should the revised Directives fall within the scope of the TBT Agreement, the affected countries could claim violation of Article 2.1 of the TBT Agreement, showing that the Directives accord to their biofuels less favourable treatment than that accorded to 'like' biofuels in the EU or imported to the EU from other countries. The 'less favourable treatment' part of the legal test would also require that the discrimination caused by the revised EU biofuels regime does not exclusively stem from a legitimate regulatory distinction. The complaining WTO member could potentially bring arguments on the lack of even-handedness of the biofuel regime (especially with respect to the threshold and the default values). Whereas the EC explicitly mentions the need for good governance and a rights-based approach to food and nutritional security, as well as the need for coherence between various policies, it can be questioned whether the measure is indeed fair in pursuing these objectives. Again, the Commission itself recognizes that production of biofuel feedstock can be achieved through improved productivity or measures alike and not necessarily by quantitative restrictions. In the absence of dedicated certification schemes that take into consideration efficiency measures, this provision is not operational in practice. Furthermore, the EU revised biofuel regime could be challenged under Article 2.2 of the TBT Agreement as it would allegedly create unnecessary obstacles to international trade and be more trade restrictive than necessary to achieve the set goals.

Article 2.4 of the TBT Agreement requires WTO Members to use relevant international standards as a basis for their technical regulations. Such technical regulations would be rebuttably presumed not to create unnecessary obstacles to international trade. Currently, there are no international standards relevant for the revised EU Directives. The EU sustainability regime for biofuels operates based on the recognition of certification schemes meeting the EU sustainability criteria for biofuels. As of April 2014, there were nineteen certification schemes that were recognized by the EC. All of them are voluntary certification schemes, which are managed by private entities, with the exception of the Roundtable for Sustainable Biomaterials (RSB), which is a hybrid entity open to private organizations, governments and intergovernmental organization active in the field of biofuels. The RSB standard for EU market access was prepared specifically to meet the requirements of the Renewable Energy Directive and Fuel Quality Directive. Following the suggested cap on first-generation biofuels, the RSB recently prepared an addition to the basic standard – 'RSB Low iLUC Risk Indicators', which aims to address the iLUC concern. In light of the hybrid nature of the RSB, a more thorough analysis would be needed to determine whether it can potentially be treated as an international standard setting organization within the meaning of the TBT Agreement.

8.5 Possible solutions outside the WTO

Given the fact that iLUC GHG emissions can be also mitigated through sustainable agricultural and biodiversity policies, one of the possible solutions is to address these issues in bilateral or multilateral agreements.

The conclusion of bilateral agreements would not ensure WTO compatibility of the revised Renewable Energy and Fuel Quality Directives, however it would allow for more flexible solutions with partner countries. These agreements could be negotiated with the key biofuel exporting countries that might be affected by the revised Directives, either specifically for the biofuels sector or in a broader framework of preferential trade agreements. Relevant examples can be found in the new generation of Free Trade Agreements (FTA). The FTA between the EU and South Korea includes provisions on biodiversity with a reference to the biofuels policy, but is rather general in nature. Another interesting example is the TPA between the US and Peru, which includes an Annex on Forest Sector Governance and led to the adoption of a law on sustainable forest governance in Peru.While bilateral agreements offer more country-specific solutions, multilateral agreements would still be a preferable option, even though it is very difficult to reach an international consensus on the desirable level of protection, as the example of climate change negotiations shows. Efforts will eventually be taken to adequately address the question of biofuels within the framework of the future Environmental Goods Agreement.To conclude, WTO law does not prevent countries to enact regulations in pursuing various legitimate objectives. Sustainability requirements for biofuels, including the iLUC criteria, can play an important role to ensure their socially and environmentally responsible production. However they should not create unjustifiable obstacles to international biofuel trade, particularly as there is no scientific certainty about the iLUC effects on food prices, biodiversity and GHG emissions. In addition, these effects would vary depending on specific conditions (geographical, economic, regulatory) in a biofuel exporting country, the sustainable biofuel policy should be designed and implemented in a way to take these differences into consideration. The question of the dual use of second-generation biofuels (waste vs feedstock, e.g. in the case of straw) should be paid due regard in the formulation of biofuels policy. Finally, threats to food security and nutrition, destruction of biodiversity and climate change are examples of common concerns, which can be best tackled through coherent international action. Whereas international consensus is not always possible, necessary efforts should be taken at the international level (e.g. development of an international standard for the life-cycle GHG emissions of biofuels or negotiations on the future Environmental Goods Agreement). Integration of provisions on the sustainability of biofuels in bilateral agreements can play an important intermediary role and offer flexible solutions for the key partners in biofuels trade. The right balance between different public policy objectives as a part of biofuel policies would also support developing countries - producers of biofuels or feedstock for biofuels - in achieving an overall higher welfare standard.

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ANNEX 1

Second-generation biofuels (ethanol)
Geographic region: USA

Existing Cellulosic ethanol plants	Project type	Products	Location	Feedstock	Production capacity (million litres/year)	Start year
Abengoa Bioenergy Biomass of Kansas LLC	TRL8 First-of-a-kind Comm Demo	Ethanol	Hugoton, United States	Corn Stover/Straw/ Switchgrass	94.64	2014
Abengoa Bioenergy Company. - Cellulosic Demo	TRL6-7 Demonstration	Ethanol	York, United States	Crop Residue	0.14	2008
Abengoa Bioenergy New Technologies	TRL 4-5 Pilot	Ethanol	York, USA	Corn stover	0.10	2007
Aemetis	TRL 4-5 Pilot	Ethanol	Butte, USA	energy grasses and corn stalks	0.64	2008
Blue Sugars Corporation	TRL6-7 Demonstration	Ethanol	Upton, United States	Sugarcane bagasse and other biomass	5.72	2008
Fulcrum (Sierra Biofuels)	TRL4-5 Pilot	Ethanol	CA, United States	unknown	0.04	2009
INEOS Bio - Indian River County Facility	TRL8 First-of-a-kind Comm Demo	Ethanol	Vero Beach, United States	Vegetative Waste, Waste wood	30.48	2013
Iowa State University - BioCentury Research Farm	TRL4-5 Pilot	FT liquids; ethanol	Boone, United States	lignocellulosic crops or residues	0.25	2009
LanzaTech - USA Mobile Demo Plant	TRL6-7 Demonstration	Ethanol	Soperton, United States	woody biomas syngas	0.09	2014
Lignol	TRL4-5 Pilot	Ethanol	Grand Junction, IA, United States	woody biomass	0.08	2009
NREL Integrated Biorefinery Research Facility (IBRF)	TRL4-5 Pilot	Ethanol	Golden, United States	lignocellulosic crops or residues	0.06	2011
Petrobras and Blue Sugars - Second generation ethanol demo plant	TRL6-7 Demonstration	Ethanol	Upton, United States	sugarcane bagasse	0.89	2011
POET - Scotland	TRL4-5 Pilot	Ethanol	Scotland, United States	corn fiber, corn cobs and corn stalks	0.08	2008

Summit Natural Energy	TRL6-7 Demonstration	Ethanol	Cornelius, OR, United States	waste material	3.82	2011
Gevo - commercial demo	TRL8 First-of-a-kind Comm Demo	Ethanol, Butanol	Luverne, MN, United States	lignocellulosic crops or residues	68.58	2006
American Process Inc. - Thomaston Biorefinery	TRL6-7 Demonstration	Ethanol	Thomaston, United States	Sugarcane Bagasse/Woody Biomass	1.14	2010
BP Biofuels Demonstration Plant, Jennings Facility	TRL 6-7 Demo	Ethanol	LA Jennings, United States	Energy Grasses	5.30	2009
Dupont Cellulosic Ethanol LLC - Vonore	TRL6-7 Demonstration	Ethanol	Vonore, United States	Switchgrass/Corn Stover	0.95	2010
Fiberight LLC Demonstration Plant	TRL6-7 Demonstration	Ethanol	Lawrenceville, United States	Municipal solid waste	1.89	2012
Fiberight of Blairstown LLC	TRL8 First-of-a-kind Comm Demo	Ethanol	Blairstown, United States	Municipal solid waste	22.71	2014
ICM Inc. Pilot Integrated Cellulosic Biorefinery	TRL4-5 Pilot	Ethanol	St. Joseph, United States	Corn Fiber/Energy Sorghum/ Switchgrass	1.21	2011
Mascoma Corp. Demo Plant	TRL6-7 Demonstration	Ethanol	Rome, United States	Mixed Hardwood / lignocellulosic material	0.76	2009
Mendota Bioenergy LLC	TRL6-7 Demonstration	Ethanol	CA	Energy Beets	3.79	2013
Poet-DSM Advanced Biofuels LLC - Project Liberty	TRL8 First-of-a-kind Comm Demo	Ethanol	Emmetsburg, United States	Corn Cobs/Corn Stover	94.64	2014
Quad County Cellulosic Ethanol Plant	TRL8 First-of-a-kind Comm Demo	Ethanol	IA	Corn kernel Fiber	7.62	2014
ZeaChem Inc. - Demonstration Plant	TRL6-7 Demonstration	Ethanol	Boardman, United States	Poplar/Straw/Stover	0.95	2011
Total plants: 27				**Total capacity in million litres:**	**346.52**	

Plants under construction as of 2015	Project type	Products	Location	Feedstock	Capacity under construction (million litres)	Expected start of operations
DuPont Cellulosic Ethanol LLC - Nevada	TRL8 First-of-a-kind Comm Demo	Ethanol	Nevada, IA, United States	Corn stover	113.56	2015
Fiberight LLC	TRL8 First-of-a-kind Comm Demo	Ethanol	Blairstown, United States	Organic residues and waste streams	22.71	2015
Lanzatech Freedom Pines Biorefinery LLC	TRL8 First-of-a-kind Comm Demo	Ethanol	Soperton, United States	Forestry residues	7.57	2015
Total plants: 2				Total capacity under construction:	143.85	

Proposed cellulosic ethanol plants	Project type	Product	Location	Feedstock	Production capacity (million litres/ year)	Start year
Advanced Biofuels Corp. - Moses Lake	TRL8 First-of-a-kind Comm Demo	Ethanol	Moses Lake, United States	Waste stream	22.71	N/A
BlueFire Renewables Fulton LLC	TRL8 First-of-a-kind Comm Demo	Ethanol	Fulton, United States	Wood waste	71.92	N/A
Canergy LLC - Rockwood Plant	TRL8 First-of-a-kind Comm Demo	Ethanol	Brawley, United States	Energy cane	105.99	2016
Beta Renewables / Chemtex - Project Alpha	TRL8 First-of-a-kind Comm Demo	Ethanol	Clinton, United States	Energy grasses	75.71	2016
Enerkem Mississippi Biofuels LLC	TRL8 First-of-a-kind Comm Demo	Ethanol	Pontotoc, United States	Municipal solid waste/ Wood residue	37.85	N/A
Sunset Ethanol Inc.	TRL8 First-of-a-kind Comm Demo	Ethanol	Fernley, United States	Switchgrass/forage Sorghum	18.93	N/A
Tama Renewable Energy Campus LLC	TRL8 First-of-a-kind Comm Demo	Ethanol	Tama, United States	Corn/cellulose	378.54	N/A
Woodland Biofuels Inc. - Newton Falls	TRL8 First-of-a-kind Comm Demo	Ethanol	Newton Falls, United States	Wood waste	75.71	N/A
ZeaChem Boardman Biorefinery LLC	TRL8 First-of-a-kind Comm Demo	Ethanol	Bordman, United States	Poplar/wheat straw	94.64	N/A
ZeaChem Boardman Biorefinery LLC	TRL8 First-of-a-kind Comm Demo	Ethanol	Bordman, United States	Poplar/wheat straw	94.64	N/A
Total proposed plants: 10			**Total capacity in million litres:**		**889.57**	

Source: Compiled from Ethanol Producer Magazine, IEA Task force 39, European Biofuels Technology Platform and Biofuels Digest.

ANNEX 2

Cellulosic ethanol plants in the EU

Cellulosic ethanol plant (existing)	Project type	Product	Location	Feedstock	Production capacity (million litres/year)	Start year
Mussi Chemtex / Beta Renewables	TRL 8 First-of-its Kind commercial demo	Ethanol	Crescentino, Italy	arundo donax, straw (rice, wheat)	75.00	2012
Abengoa	TRL 6-7 Demonstration	Ethanol	Babilafuente (Salamanca), Spain	organic residues / waste streams	1.50	2013
Clariant - sunliquid	TRL 6-7 Demonstration	Ethanol	Munich (Straubing), Germany	wheat straw	1.20	2012
Inbicon (DONG energy)	TRL 6-7 Demonstration	Ethanol	kalundborg, Denmark	wheat straw	5.40	2009
Beta Renewables /Mussi chemtex/TPG	TRL 4-5 Pilot	Ethanol	Piedmont, Italy	straw	0.38	2012
Beta Renewables (PILOT)	TRL 4-5 Pilot	Ethanol	Rivalta Scrivia, Italy	corn stover, straw, husk, energy crops (Giant Reed)woody biomass	0.06	2009
BioGasol - BornBioFuel 1 (PILOT)	TRL 4-5 Pilot	Ethanol	Ballerup, Denmark	lignocellulosic crops or residues	1.00	2008
Borregaard AS - BALI Biorefinery Demo	TRL 6-7 Demonstration	Ethanol	Sarpsborg, Norway	sugarcane bagasse, straw, wood, energy crops, other lignocellulosics	0.14	2012
Borregaard Industries AS - ChemCell Ethanol	TRL 8 First-of-its Kind commercial demo	Ethanol	Sarpsborg, Norway	woof pulping residues	20.00	1938 (pulping site)
Chempolis Ltd.	TRL 6-7 Demonstration	Ethanol	Oulu, Finland	non-wood and non-food lignocellulosic biomass such as straw, reed, empty fruit bunch, bagasse, corn stalks, as well as wood residues	6.34	2008
Domsjo Fabriker (DEMO)	TRL 6-7 Demonstration	Ethanol	Ornskoldsvik, Sweden	softwood / residue from pulp mill	11.07	1930
Procethol 2G (PILOT)	TRL 4-5 Pilot	Ethanol	Pomacle, France	flexible woody and agricultural by-products, residues, energy crops	3.50	2011

Scottish Bioenergy	TRL 4-5 Pilot	Ethanol	Glenturret, Scotland, UK	algae microbial and aquatic biomass	0.04	2009
SP/EPAP Biorefinery Demo Plant	TRL 6-7 Demonstration	Ethanol	Ornskoldsvik, Sweden	primary wood chips sugarcane bagasse, wheat, corn stover, energy grass, recycled waste	0.20	2004
Abengoa	TRL 6-7 Demonstration	Ethanol	Babilafuente (Salamanca), Spain	cereal straw (barley and wheat)	5.00	2008
Inbicon (DONG energy) Pilot 1	TRL 4-5 Pilot	Ethanol	Fredericia, Denmark	straw	N/A	2003
Inbicon (DONG energy) Pilot 2	TRL 4-5 Pilot	Ethanol	Fredericia, Denmark	lignocellulosic crops or residues	N/A	2005
Inbicon (DONG energy) Pilot 2	TRL 4-5 Pilot	Ethanol	Fredericia, Denmark	Lignocellulosic crops or residues	N/A	2005
Total plants: 27				**Total capacity in million litres:**	**130.83**	

Cellulosic ethanol plant (planned)	Project type	Product	Location	Feedstock	Production capacity (million litres/ year)	Start year
SEKAB	TRL 6-7 Demonstration	Ethanol	Goswinowice, Poland	wheat straw and corno stover	63.37	N/A
ST1 - Cellulonix	TRL 6-7 Demonstration	Ethanol	Kajaani, Finland	sawdust	10.00	2016
Maabjerg Energy Concept Consortium (Planned)	TRL 8 First-of-its Kind commercial demo	Ethanol, biogas, CHP	Holstebro, Denmark	plant dry matter, manure	77.00	2017
FibreEtOH	TRL 8 First-of-its Kind commercial demo	Ethanol	Helsinki, Finland	fibres from paper production	20.00	N/A
Suomen Bioetanoli Oy plant	TRL 8 First-of-its Kind commercial demo	Ethanol	Kouvala, Finland	byproducts from sawmill	90.00	N/A
BioTfuel-consortium	TRL 8 First-of-its Kind commercial demo	Ethanol	Dunkerke, France	forest waste, straw, dedicated energy crops	254.00	N/A
Abengoa Lacq Project	TRL 8 First-of-its Kind commercial demo	Ethanol	Lacq, France	gasified corn harvest and forest residues	80.00	N/A
Beta Renewables Portovesme project	TRL 8 First-of-its Kind commercial demo	Ethanol	Portovesme, Italy	green waste	100.00	N/A
Energochemica SE / Chemtex	TRL 8 First-of-its Kind commercial demo	Ethanol	Kosice, Slovakia	non-food biomass (unspecified)	69.85	N/A
Abengoa	TRL 8 First-of-its Kind commercial demo	Ethanol	Seville, Spain	organic residues / waste streams	28.18	2016
Total plants: 27			**Total capacity in million litres:**		**792.41**	

* Many of the listed facilities also produce biochemicals and biomaterials as co-products.
Source: http://www.biofuelstp.eu/demorecords.php?pageNum_ebtp_dem=0&totalRows_ebtp_dem=105&biofs=ethanol&feedtype=&convtech=&democountry=&projtype=&keyword=&Search=Search
Additional Source: John Neeft Netherlands Enterprise Agency

ANNEX 3

Second-generation biofuels. Geographic region: Brazil

Cellulosic ethanol plant (existing)	Project type	Products	Location	Feedstock	Production capacity (million litres/ year)	Start year
GranBio / Beta Renewables/ Chemtex	TRL 8 First-of-its Kind commercial demo	Ethanol	Sao Miguel, Brazil	Sugarcane bagasse and straw	82.38	2014
Cane Technology Center (CTC)	TRL 8 First-of-its Kind commercial demo	Ethanol	Piracicaba, SP, Brazil	Sugarcane bagasse	50.70	2012
Raizen Energia	TRL 6-7 Demonstration	Ethanol	Costa Pinto, Piracicaba, Brazil	Bagasse	40.26	2015
Petrobras - pilot	TRL 4-5 Pilot	Ethanol	Rio de Janeiro, Brazil	Sugarcane bagasse	4.00	2007
				Total capacity in million litres:	**177.34**	

Source: Compiled from Ethanol Producer Magazine, IEA Task force 39, European Biofuels Technology Platform and Biofuels Digest. Total Plants: 27

ANNEX 4

Cellulosic ethanol plants in China

Cellulosic ethanol plant (existing)	Project type	Products	Location	Feedstock	Production capacity (million litres/ year)	Start year
Beta Renewables - Fuyang Bioproject	TRL 8 First-of-its Kind commercial demo	Ethanol	Fuyang, China	Wheat straw, corn stover, poplar residues	253.49	2016
COFCO Zhaodong Co. (PILOT)	TRL 4-5 Pilot	Ethanol	Zhaodong, China	Corn stover	0.44	2006
Energy & Chemical Department of East China University of Science and Technology - (PILOT)	TRL 4-5 Pilot	Ethanol	Dongchuan, China	Crop and forestry residues	0.82	2005
Henan Tianguan Group - Henan 1	TRL 6-7 Demonstration	Ethanol	Henan, China	Wheat/corn stover	3.80	2009
Jilin Fuel Alcohol - Jilin 1	TRL 6-7 Demonstration	Ethanol	Jilin, China	Corn/sorghum stover/ straw	3.80	2008
Jilin Fuel Alcohol - Jilin 2	TRL 6-7 Demonstration	Ethanol	Jilin, China	Corn/sorghum stover/ straw	3.80	2006
LanzaTech (Beijing Shougang LanzaTech New Energy Technology Co., Ltd.) - Waste Gas to Fuel	TRL 6-7 Demonstration	Ethanol	Beijing, China	Industrial off gas	0.09	2013
LanzaTech BaoSteel New Energy Co., Ltd. - Pilot at BaoSteel Steel Mill	TRL 6-7 Demonstration	Ethanol	Shanghai, China	Industrial flue gasses	0.38	2012
WBT - LanzaTech Taiwan	TRL 6-7 Demonstration	Ethanol	Taiwan, Province of China	Steel flue gas	0.05	2014
Shandong Zesheng Biotech Co. - demo	TRL 6-7 Demonstration	Ethanol	Shandong, China	Straw	3.80	2006
Anhui BBCA Biochemical	TRL 6-7 Demonstration	Ethanol	Anhui, China	Corncob/corn stover	6.34	2009
Longlive Bio-technology Co. Ltd. - commercial demo	TRL 8 First-of-its Kind commercial demo	Ethanol	Yucheng, Shandong, China	Corn cob	63.37	2012
Total plants: 27				**Total capacity in million litres:**	**340.19**	

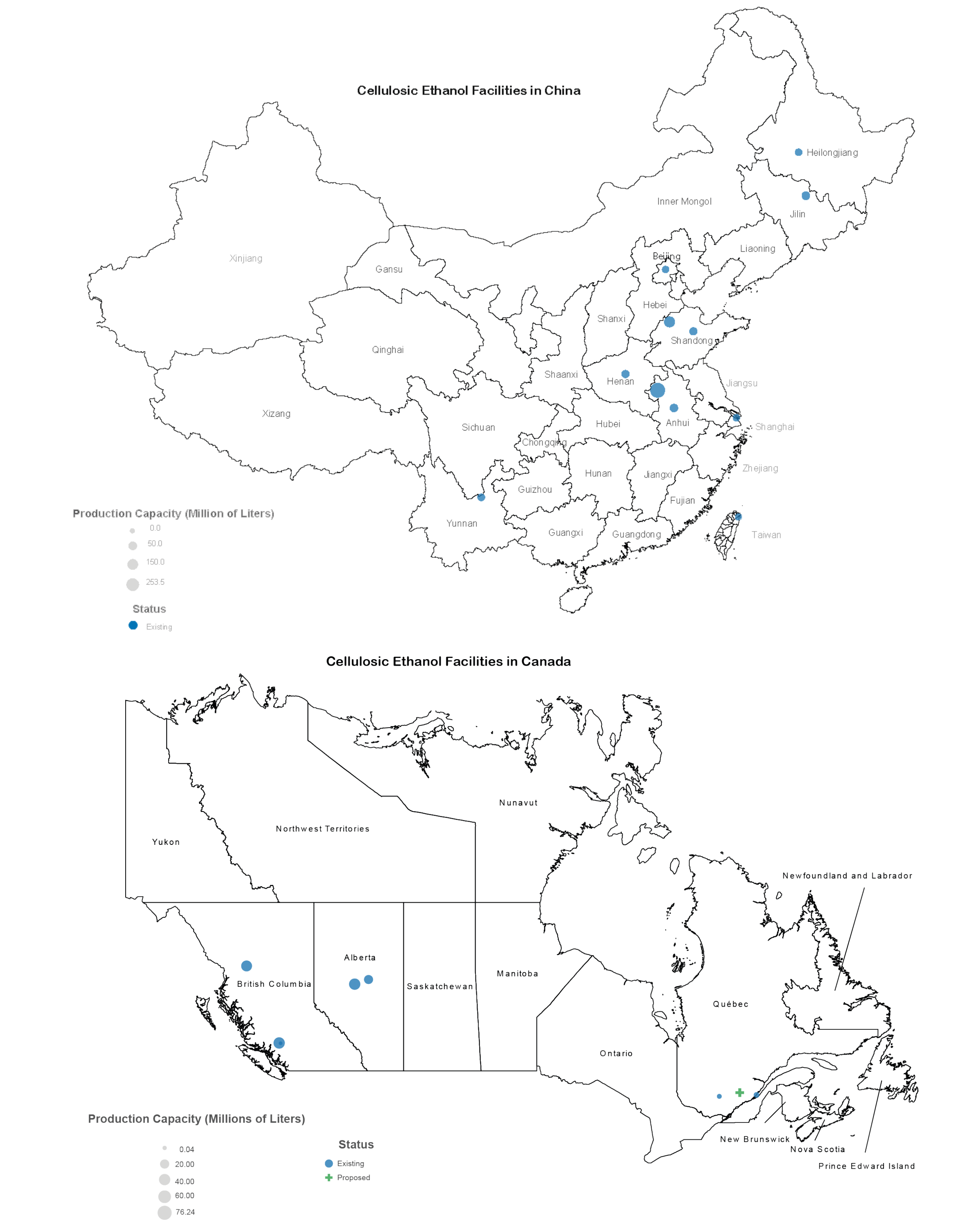
ANNEX 5

Cellulosic ethanol plants in Canada

Cellulosic ethanol plant (existing)	Project type	Product	Location	Feedstock	Production capacity (million litres/ year)	Start year
Core biofuels	TRL6-7 Demonstration	Ethanol	Houston, BC, Canada	Sawmill waste & roadside residues	67.82	2015
Vanerco (Enerkem & Greenfield Ethanol)	TRL6-7 Demonstration	Ethanol	Varennes, PQ, Canada	Sorted waste	38.02	Planned
Mascoma - commercial demo	TRL8 First-of-a-kind Comm Demo	Ethanol	Drayton, Alberta, Canada	Wood	76.20	2015
Lignol - Demo	TRL6-7 Demonstration	Ethanol; butanol	Vancouver, BC, Canada	Hardwood	76.20	2015
Lignol - Pilot	TRL4-5 Pilot	Ethanol	Vancouver, BC, Canada	Unknown	0.04	2009
Lignol Innovations Ltd. - pilot	TRL4-5 Pilot	Ethanol	Burnaby, Canada	Hardwood & softwood residues	0.04	2009
Iogen Corporation - demo	TRL6-7 Demonstration	Ethanol	Ottawa, Canada	Lignocellulosic crops or residues	2.03	2004
Enerkem Alberta Biofuels LP	TRL8 First-of-a-kind Comm Demo	Ethanol	Edmonton, Canada	Post-sorted municipal solid waste	38.02	2014
Enerkem - Westbury commercial demo	TRL6-7 Demonstration	Ethanol	Westbury, Canada	Treated wood	5.07	2009
Total plants: 9				**Total capacity in million litres:**	**303.45**	

ANNEX 6

Advanced cellulosic ethanol plants in Canada and China



Sources: IEA task force 39; Ethanol Producer Magazine, 2015; Direct industry interviews. Credits: Duke Center for Sustainability & Commerce

Notes

1 That publication updated the earliest market and policy study in the area carried out by the organization in 2006 (UNCTAD, 2006).

2 Such as the United States, Brazil, the European Union (especially Germany and France), China, Canada, India, Argentina, Malaysia, Indonesia and Australia.

3 UNCTAD (2014) The State of the Biofuels Market: Regulatory, Trade and Development Perspectives. Available at: http://unctad.org/en/pages/PublicationWebflyer.aspx?publicationid=1059.

4 https://sustainabledevelopment.un.org/topics.

5 The RSB is the first organization to deploy a standard for certifying low iLUC risk biomaterials.

6 See: http://www.ecofys.com/files/files/ecofys-epfl-wwf-2013-credible-robust-certification-of-low-iluc-biofuels.pdf.

7 http://www.millenniumassessment.org.

8 Litre of diesel or petrol equivalent.

9 See: http://www.iea.org/publications/freepublications/publication/biofuels_roadmap_web.pdf.

10 For the definition of the highly biodiverse grassland, see: Commission Regulation (EU) No 1307/2014 of 8 December 2014 on defining the criteria and geographic ranges of highly biodiverse grassland for the purposes of Article 7b(3)(c) of Directive 98/70/EC of the European Parliament and of the Council relating to the quality of petrol and diesel fuels and Article 17(3)(c) of Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, OJ L 351, 9.12.2014, p. 3.

11 See Article 17(1) of the Renewable Energy Directive.

12 Article 7a(1) of the Fuel Quality Directive and Article 3(4)(d) of the Renewable Energy Directive as amended by the Commission's proposal COM (2012) 595, 2012/0288 (COD), (hereinafter referred to as the 'Proposal'). In April 2015 the European Parliament reached a political agreement on the current version of this Proposal.

13 Member States have a possibility to introduce targets lower than 7% at the national level. See Recital 13 of the Proposal.

14 Biofuelstp.eu, (2015). Biofuels Legislation in Europe. [online] Available at: http://www.biofuelstp.eu/biofuels-legislation.html [Accessed 1 Sep. 2015].

15 European Parliament, (2015). Parliament supports shift towards advanced biofuels PLENARY SESSIO. [online] Available at: http://www.europarl.europa.eu/news/en/news-room/content/20150424IPR45730/html/Parliament-supports-shift-towards-advanced-biofuels [Accessed 23 Aug. 2015].

16 Article 3(4)(d) of the Renewable Energy Directive according to the Proposal.

17 European Biodiesel Board, (2015). Biodiesel Chain relief at European Parliament plenary adoption of imperfect agreement on ILUC. [online] Available at: http://www.ebb-eu.org/EBBpressreleases/PR_EOA_Fediol_EBB_ILUC_28apr2015_rg%20FINAL.pdf [Accessed 13 Aug. 2015].

18 Fischer, G., Hizsnyik, E., Prieler, S. and van Velthuizen, H. (2007). Assessment of biomass potentials for biofuel feedstock production in Europe: Methodology and Results. [online] International Institute for Applied System Analysis. Available at: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/refuel_assessment_of_biomass_potentials.pdf [Accessed 16 Aug. 2015].

19 Ibid p. 50.

20 Ibid.

21 International Renewable Energy Agency, (2010). Sustainable Production of Second-Generation of Biofuels. [online] OECD/IEA. Available at: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/refuel_assessment_of_biomass_potentials.pdf [Accessed 6 Sep. 2015].

22 See REmap report: http://irena.org/remap/IRENA_REmap_Report_June_2014.pdf.

23 van Zyl et al (2011).

24 Source EIA, International Energy Statistics: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=79&pid=79&aid=1.

25 van Zyl et al (2011).

26 Source EIA http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=79&pid=79&aid=1.

27 Source: Africa Energy Outlook, OECD/IEA (2014).

28 Source Biofuels Digest: http://www.biofuelsdigest.com/bdigest/2014/12/31/biofuels-mandates-around-the-world-2015/.

29 Source Biofuels Digest and Boing: http://www.biofuelsdigest.com/bdigest/2014/12/10/tobacco-planting-

underway-for-boeing-and-saas-aviation-biofuel-project/ http://boeing.mediaroom.com/2014-12-09-Boeing-South-African-Airways-Look-to-First-Harvest-of-Energy-Rich-Tobacco-to-Make-Sustainable-Aviation-Biofuel.

30 Republic of South Africa (2014).

31 The initial target of the programme was the installation of 14 000 biogas plants.

32 http://africabiogas.org/ethiopia/.

33 Source ABPP.

34 Source Biofuels digest: http://www.biofuelsdigest.com/bdigest/2013/10/31/nigerian-company-spreading-biofuel-cookstoves-to-west-africa/.

35 Source: UN Statistics Division Energy Statistics Database, 2015. (data downloaded from knomea.com).

36 At the time of writing all of them are pending at the stage of consultations or panel proceedings: DS443, *EU and a Member State – Certain Measures Concerning the Importation of Biodiesel* (complaint submitted by Argentina; in consultation since 17 August 2012). In its complaint Argentina primarily raised concerns with regard to the Spanish Order implementing the Renewable Energy Directive, which regulates allocation of quantities of biodiesel needed to achieve the mandatory target of renewable energy. DS459, *EU and Certain Member States – Certain Measures on the Importation and Marketing of Biodiesel and Measures Supporting the Biodiesel Industry* (complaint submitted by Argentina; in consultations since 15 May 2013). In DS459 Argentina addressed specifically the Renewable Energy and the Fuel Quality Directives, namely the saving threshold of at least 35 per cent of greenhouse gas emissions with respect to fossil fuels. At the same time, the default values assigned to biodiesel from soybean is only 31 per cent. Based on this default value biodiesel from soybean mainly produced in Argentina would not comply with the EU sustainability requirements. DS473, *EU – Anti-Dumping Measures on Biodiesel from Argentina* (complaint submitted by Argentina; the panel composed on 23 June 2014); DS480, *EU – Anti-Dumping Measures on Biodiesel from Indonesia* (complaint submitted by Indonesia; in consultations since 10 June 2014). The last two cases are dealing with the anti-dumping duties imposed in November 2013 by the EU on imports of biodiesel from Argentina (24.6%) and Indonesia (18.9%) for duration of five years.

37 Article XVI GATT, Agreement on Subsidies and Countervailing Measures (ASCM); Article 6 and Annex 2 of the Agreement on Agriculture (AoA). The latter is of relevance for ethanol, which is classified under Chapter 22 of the Harmonized System of the World Customs Organisation (WCO) and according to Annex 1 to the AoA falls within its scope.

38 Panel Report, *India – Measures Affecting the Automotive Sector*, WT/DS146/R, WT/DS175/R, 21 December 2001, para. 7.224.

39 Panel Report, *Argentina – Measures Affecting the Export of Bovine Hides and the Import of Finished Leather*, WT/DS155/R, paras. 11.21-11.22.

40 See a view on how the EU could invoke Article XX GATT to justify its old biofuels regime, which is also partly relevant to the new biofuels regime: J. Grigorova, 'EU's Renewable Energy Directive saved by GATT Article XX?', OGEL/TDM Special Issue on "Renewable Energy Disputes", 13(3), March 2015.

41 Recitals 4 – 18a of the revised Fuel Quality Directive.

42 Recital 19 of the revised Fuel Quality Directive.

43 In the US-COOL and US-Tuna II cases the challenged regulations were dealing with the labelling schemes which per se fall under the purview of the TBT Agreement.

44 Recital 18a of the Proposal.

45 Recital 19 of the Proposal.

46 Article 2.5 of the TBT Agreement.

47 These 19 certification schemes as of May 2015 include: International Sustainability and Carbon Certification (ISCC), Bonsucro EU, RTRS EU RED (Round Table on Responsible Soy EU RED), RSB EU RED (Roundtable of Sustainable Biofuels EU RED), Biomass Biofuels Voluntary Scheme (2BSvs), Abengoa RED Bioenergy Sustainability Assurance (RBSA), Greenergy (Greenergy Brazilian Bioethanol Verification Programme), Ensus (Voluntary scheme under RED for Ensus bioethanol production), Red Tractor (Red Tractor Farm Assurance Combinable Crops and Sugar Beet Scheme), Scottish Quality Farm Assured Combinable Crops (SQC) scheme, Red Cert, NTA 8080, Roundtable on Sustainable Palm Oil RED (RSPO RED), Biograce GHG calculation tool, HVO Renewable Diesel Scheme for Verification of Compliance with the RED Sustainability Criteria for Biofuels, Gafta Trade Assurance Scheme, KZR INIG System, Trade Assurance Scheme for Combinable Crops, Universal Feed Assurance Scheme. The up-to-date list is available at: https://ec.europa.eu/energy/en/topics/renewable-energy/biofuels/voluntary-schemes (accessed 09.08.2015). Notably, Argentina in its WTO claim DS459 challenged also the conformity assessment procedures applied by the EU to recognize foreign certification schemes for biofuels.

48 See the RSB membership requirements: http://rsb.org/membership/why-become-a-member/ (accessed

09.08.2015).

49 RSB Standard for EU Market Access, RSB-STD-11-001 (Version 2.6), 19 May 2015.

50 For the interpretation of the term 'international standard setting organisation' see: Decision of the Committee on Principles for the Development of International Standards, Guides and Recommendations with relation to Articles 2, 5 and Annex 3 of the Agreement, G/TBT/1/Rev.9, Decisions and Recommendations adopted by the WTO Committee on Technical Barriers to Trade since 1 January 1995, 8 September 2008, 37-39.

51 On the relationship between the dispute settlement in the FTAs and WTO see e.g.: Appellate Body Report, *Peru – Additional Duty on Imports of Certain Agricultural Products*, WT/DS457/AB/R, 31 July 2015.

52 FTAs give a possibility to offer technical support and technology transfer to countries-partners, which could serve as an additional incentive to comply with the EU biofuels sustainability regime.

53 Article 18(4) of the Renewable Energy Directive encourages conclusion of bilateral and multilateral agreements containing sustainability criteria for biofuels.

54 Also mentioned in Recital 15 of the Fuel Quality Directive.

55 See on the role of bilateral agreements to promote sustainable biofuels: C. Johan Westberg, Francis X. Johnson, 'The Path not Yet Taken: Bilateral Trade Agreements to Promote Sustainable Biofuels under the EU Renewable Energy Directive', 44 Environmental Law Reporter News and Analysis 10607 (2014); Arlo Poletti, Daniela Sicurelly, The European Union, preferential trade agreements, and the international regulation of sustainable biofuels, Journal of Common Market Studies (forthcoming December 2015).

56 Annex 13 on Trade and Sustainable Development of the Free Trade Agreement between the European Union and its Member States, of the one part, and the Republic of Korea, of the other part, OJ L 127, Volume 54, 14 May 2011 at 6.

57 United States - Peru Trade Promotion Agreement, signed on 12 April 2006, entered into force on 1 February 2009.

58 In July 2014, fourteen WTO Members launched plurilateral negotiations on an Environmental Goods Agreement. Currently negotiations are limited to WTO Members only, but potentially will be expanded to non WTO Members. See: 'Azevedo welcomes launch of plurilateral environmental goods negotiations', WTO: 22014 News Items, 8 July 2014, <http://www.wto.org/english/news_e/news14_e/envir_08jul14_e.htm> accessed 11 January 2015.