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BIOFUEL USE: PECULIARITIES AND IMPLICATIONS

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Abstract. Transport biofuels are currently the fastest growing bioenergy sectors even they represent around 3-4% of total road transport fuel and only 6% of total bioenergy consumption today. Low oil prices and poor margins continue to challenge biofuel producers in Europe. Under current market conditions it is unlikely that the 7% cap will be reached in the EU by 2020. Since the past ten years, production of biodiesel from waste and animal fats has taken off, while the commercialization of cellulosic ethanol is lagging behind compared to former targets. Co-products are supposed to be credited with the area of cropland required to produce the amount of feed they substitute. If co-products are taken into account, the net use of land and feedstocks declines. Most existing biofuel regulations significantly undervalue the contribution of co-products when assessing the net land use and GHG impacts of biofuel production. Long-term transport shares are the most challenging to project because the range of possible vehicle technologies and fuel types in the future is very broad and future oil prices are uncertain. It is concluded that the rise in the use of biofuels has slowed down and sustainability criteria have been established regarding the use of land and the mitigation of environmental impacts caused by biofuel production.

Keywords: bioenergy supply, transport biofuels, co-products, capping, land use

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JEL Classifications: Q41, Q42, Q43

1. Introduction

Energy consumption is still increasing rapidly, with approximately 570 EJ consumed at the primary energy level in 2014. The world gets about 19.2% of its energy from renewables, including about 8.9% from traditional biomass and about 10.3% from modern renewables (Figure 1). The “traditional” share of biomass has been relatively stable for many years, while the “modern” share has grown since the late 1990s (REN21, 2015;

Ślusarczyk, et al., 2016). Traditional solid biomass and hydroelectricity still dominate renewable energy consumption on a global scale. At present, some 76 EJ/year of renewable energy is consumed globally (IEA, 2016; Navickas et al., 2017). In the past, biomass was primarily limited to woody feedstocks but today bioenergy resources range from residues, through by-products from the food industry to dedicated energy crops, post-consumer organic wastes and possibly to aquatic biomass. In 2014, investments in solar and wind energy together accounted for 92% of total global renewable energy source investments. Biofuels experienced a steady growth in new investment from 2004 to 2007, but after 2008 investments in biofuels started to decline and fluctuate at lower levels due to uncertainties over future legislation, delayed development of second generation biofuels and relatively high costs (IEA, 2016).

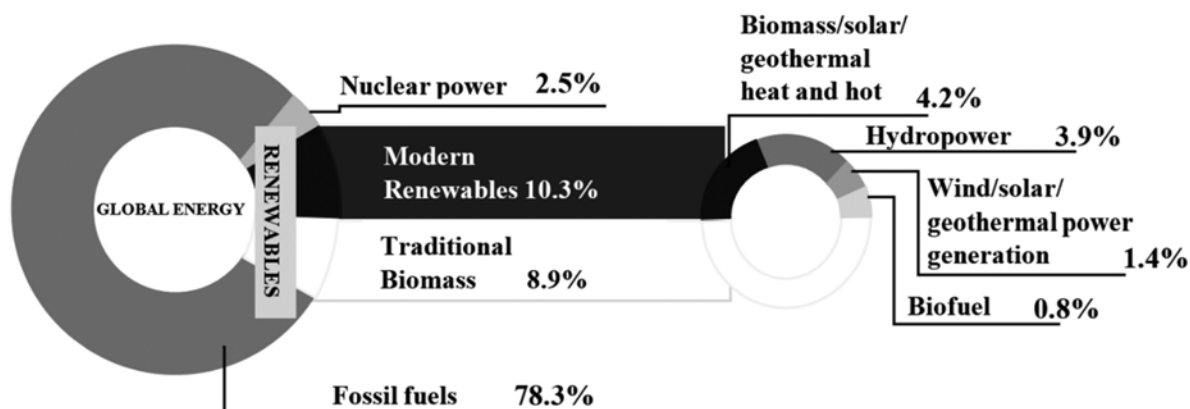


Fig. 1. Estimated renewable energy share of global final energy consumption in 2014.

Source: IEA (2016)

Recent estimates on the potential global ligno-cellulosic bioenergy supply range from less than 100 EJ/year to 1 500 EJ year for 2050. In other energy scenarios, bioenergy use is projected to be in the order of 150-400 EJ in the year 2100 (Smeets et al., 2007; IEA Bioenergy, 2009; Dornburg et al., 2010; Haberl et al., 2010; Global Energy Assessment, 2012). Around 28% of final world energy consumption can be accounted for by the transport sector, and transport biofuels are – at present – the most rapidly growing bioenergy sectors, despite currently representing only about 4% of total road transport fuel, and only 6% of total bioenergy consumption (IEA, 2015).

EU renewable energy targets are similar in principle to renewable portfolio standards in the USA, where most states have binding or non-binding standards. Increased use of agricultural land for the production of renewable energy has strengthened the link between developments in agricultural commodity and energy prices. The EU-28 share of renewable energy increased to 16,7 in 2015, already surpassing the target level (Eurostat, 2017). The gross final consumption of biofuels has slowed and more or less stalled since 2010.

The objective of this study is to analyse implications of transport biofuel use for energy, agriculture and environment. This paper provides a comprehensive review on global bioenergy, especially transport biofuels production and potentials, including different feedstock sources. The impacts on food production, economy agriculture and environment are also discussed. Moreover, biofuels policy in the US and EU determined by capping food-based biofuels is examined. This study generally focuses on global bioenergy production, however, the European Union’s policy objective of achieving 20% GHG emission reductions using 20% of renewables by the year 2020 is presented as well. Finally, the impact of substitution of traditional animal feed with co-products of biofuel production on the land use of feedstocks is also addressed. It is concluded that the rise in the use of biofuels has slowed down and sustainability criteria have been established regarding the use of land and the mitigation of environmental impacts caused by biofuel production.

2. Methodology

The literature on the impacts of biofuel expansions is already substantial, however, economic and environmental implications (Pacana and Ulewicz, 2017; Dobrovolskienė et al., 2017), and sustainability criteria established regarding the use of land and the mitigation of environmental impacts caused by biofuel production have received much less attention. Furthermore, most existing biofuel regulations significantly undervalue the contribution of co-products when assessing the net land use and GHG impacts of biofuel production. The search platform Web of Knowledge and search engine Google Scholar have been primarily used to collect the relevant literature. The combinations of following terms were used to search relevant studies: food-, energy- and environmental security, renewable energy, biomass, biofuels, co-products for livestock feeding, land-use change, sustainability criteria and climate change mitigation.

The literature reviewed is selective and critical. Highly rated journals in scientific indexes and recognised international organizations (FAO, USDA, EU, OECD, RFA etc.) are the preferred choice. We have carefully selected 53 papers and studies which are considered as important or innovative studies, or comprehensive reviews offering a big picture of the role of biofuels in economy, agriculture and environment. In addition, we also conducted supplemental searches by examining bibliographies of articles for additional references. References of the paper covered the period 2009 to 2017. Results are potentially biased because studies might differ in their focus on potential or realised effects and their use of different baselines for comparisons. In addition, there is a lack of available publications related to the feed value of increasing biofuels co-products.

3. Liquid biofuels production in the world

Currently, most attention is focused on liquid biofuels, even though just a limited proportion of biomass is employed for production of biofuels at present. Liquid biofuels contribute in a limited but increasingly important way to global transport fuel demand, currently making up about 3-4% of all road transport fuels globally, and approximately 5% (3.5 EJ/year) of bioenergy. There is also restricted but growing use in both aviation and marine sectors. At present, of the total global production of liquid biofuels around 80% takes the form of ethanol, the global production of which climbed to 116 billion litres in 2015, while for biodiesel production the global figure was 31 billion litres (OECD/FAO, 2016). The leading bioethanol producer is the USA, and together with Brazil they made up 75% of total production (Figure 2).

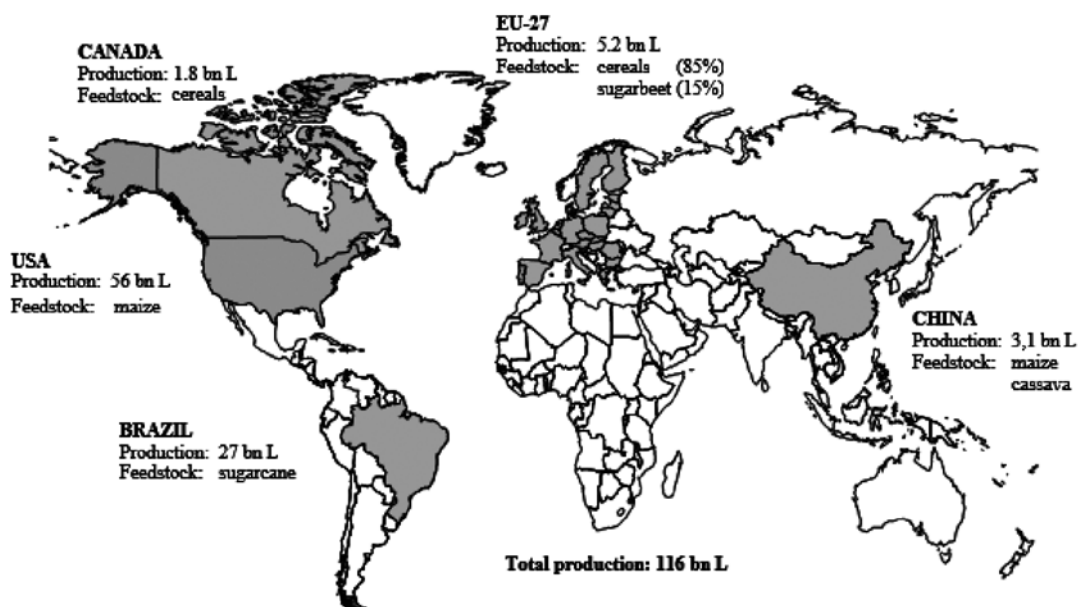


Fig. 2. World ethanol production, 2015

Source: OECD/FAO (2016); RFA (2016)

Over the next decade the projections are that the growth in global biofuel production will continue, even though not at such a dramatic rate in the second half of the decade. The global production of ethanol is also projected to grow, although more modestly, from 116 billion litres to 128 billion in the period between 2015 and 2025. The lion's share of this growth is expected to occur in Brazil and Thailand. Global biodiesel production is expected to increase from 31 billion litres in 2015 to 41 billion litres by 2025. The expansion of global biodiesel production will be driven by biofuels policies in place in the USA, the EU, Argentina, Brazil and Indonesia. The production of bioethanol is much more concentrated than ethanol, with the EU retaining its role as the centre of global production – its output of 12.5 billion litres in 2015 accounted for approximately 40% of total output, followed by the USA with 5.3 billion, and Brazil with 4.1 billion litres (Figure 3).

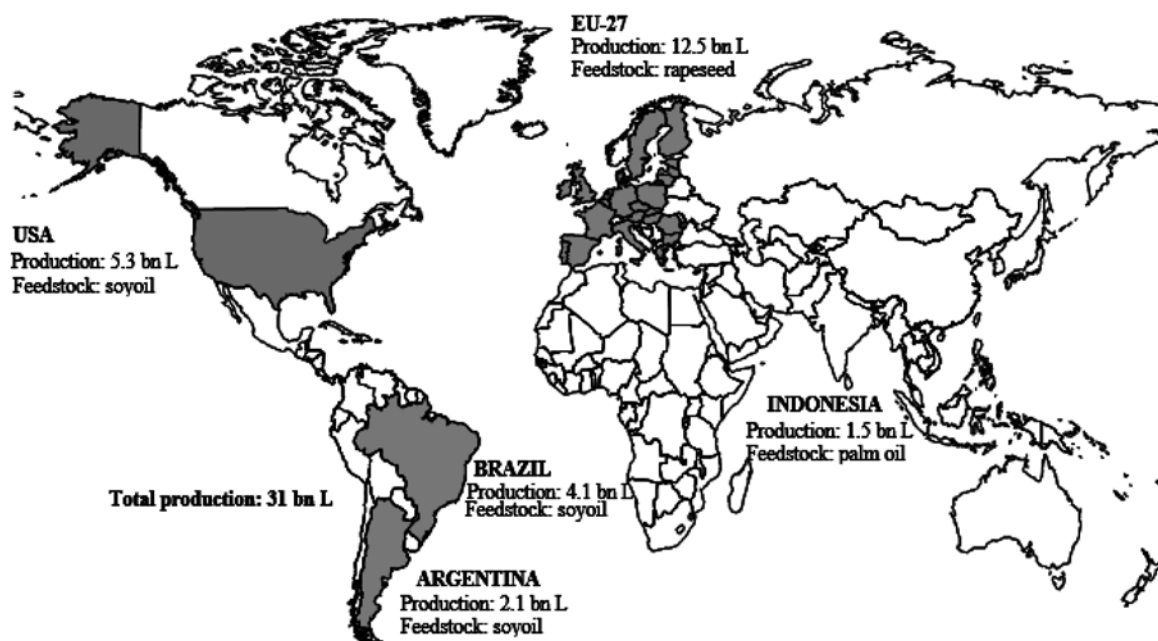


Fig. 3. World biodiesel production, 2015.

Source: OECD/FAO (2016), Statista (2016)

Coarse grains, sugarcane and molasses (in India) will continue to retain their dominance as ethanol feedstock, with vegetable oil the feedstock in biodiesel production. Almost all US production of ethanol uses corn as a feedstock. Even with the decline in US ethanol production, demand for corn to produce ethanol continues to have a strong presence in the sector, accounting for over a third of total US corn use throughout the period of 2015-2025. By 2025, 22% of global sugarcane and 10-11% of global coarse grains production is expected to be used to produce ethanol. Further projections indicate that ligno-cellulosic biomass based ethanol will make up less than 1% of world ethanol production, while biodiesel production will consume 12% of vegetable oil production globally. The production of biodiesel based on non-agricultural feedstock and especially on waste oil and tallow will develop in the EU and the United States (OECD/FAO, 2016).

A very large number of countries have blending mandates and/or targets for future shares of biofuels in transport. Nevertheless, long-term transport shares are the most challenging to project, and the most uncertain, because the range of possible vehicle technologies and fuel types in the future is very broad, future oil prices are uncertain, and technological progress from vehicle batteries to advanced biofuels, remains unpredictable. These factors create uncertainty about what future transport systems will look like. Several scenarios project shares of transport fuels; however, projections vary widely.

3.1. Economic implications

The possible impact of developed countries' biofuels policies on global food prices became a significant concern in 2007, when global grain prices reached historic heights. Though some experts associated the unprecedented price spikes in food grain and oilseed with these countries' biofuels policies (De Gorter et al., 2013), there is general agreement that these policies were probably not the root cause, although they could well have been a factor, since biofuel policy can only be blamed for a fraction of the price increases in food grain commodities (Durham et al., 2012). The recent World Bank report (Baffes and Dennis, 2013) concludes that increases in oil prices, changes in stocks and exchange rates, and not biofuel expansion, were the reasons for agricultural commodity price increases since 2004. It adds that 66% of the price increases in biofuel feedstock commodities such as wheat and corn over the last decade were due to the oil price, with the contribution of biofuels too small to quantify. In fact, the FAO Food Price Index in 2016 (January-September) in real terms was lower than it was in 2007 (FAO, 2016). This is a clear indication of a decoupling of biofuel production growth, which has grown steadily over the past decade. Oláh et al. (2017) research demonstrates the fact that an increasing biofuel production has strengthened the link between food and oil prices, especially for those food products that are used for a biofuel production. Furthermore, generally commodity prices are only small elements in final food product prices, and the prices of other elements, such as processing, packaging, marketing, and distribution are unrelated to farming. Another study has calculated that between 2000 and 2010 EU demand for biofuels caused a 1% to 2% increase in world grain prices and a 4% increase in oilseed prices. They also predicted that unless a cap is introduced on crop-based biofuels, EU policy could push grain prices up by 1%, and oilseed prices by 10% by 2020 (Hamelinck, 2013).

There are legitimate worries about the role of food crops in the energy sector, which has led (among other things) to a cap by the Renewable Fuel Standard on maize ethanol volumes at 15 billion gallons (equivalent to around 130-140 million tonnes of maize used as feedstock). In simple terms this means that if biofuels are to increase their role in the transport sector in the United States, they must come from feedstocks. In the EU new legislation limits the contribution of biofuels derived from sugars, starch, and oil crops to 7% due to sustainability concerns, which are mainly about indirect land-use change.

Biofuel co-products often substitute for higher priced feeds in animal rations. The increased use of agricultural commodities for biofuels has led to higher costs for animal feeds; however, increased substitution of co-products for traditional feedstuffs in feed rations mitigate the input cost increases faced by livestock and poultry producers. Growth in the use of agricultural commodities for biofuels is expected to continue in the next 10 years, but with growth rates slowing in key producing countries as government-imposed limits on grain use for biofuels are reached and new non-agricultural feedstocks are commercialized (OECD/FAO, 2016; USDA, 2016). The global supply of grain and oilseed has increased significantly over recent years and the greater use of these commodities for biofuels production has not caused any reduction in their availability for use as feed or food. As the use of feedstock for biofuel production stabilises in accordance with slowing national mandates, in the long term there is expected to be an increase in the amount of grain and oilseeds used for other purposes than ethanol and biodiesel production.

Prices of Dried Distillers Grains with Solubles (DDGS) and maize are highly correlated, and this correlation has strengthened in recent years. Soy and rapeseed meals have always been a major component of animal feeds, because they are excellent sources of protein. The impact of increased ethanol production is largely felt through competing crops as increased production of DDGS and oilseed meals can jointly reduce the livestock industry's demand for maize and oil meals, and offset the increase in the ethanol industry's demand for grains due to the US and EU biofuel mandates. With increasing biofuel output the production of these co-products also increases. Prices of co-products are highly correlated with prices of feedstocks, such as grains and oilseeds, and they represent an important component of total industry revenues. As a result, co-products prices fall relative to other feed ingredients. This encourages livestock producers to use more biofuel co-products in their production processes. On the other hand, any reduction in the prices of co-products diminishes total revenue and acts as a brake on the growth of the biofuel industry. Biofuel co-products function as both a shock absorber and a price adjuster (RFA, 2014).

3.2. Environmental implications

At present, around 2% of the 1.515 billion ha which makes up the total global crop area (FAO, 2013) is given over to biofuel crops cultivation, and changes in land use accompanying bioenergy account for only about 1% of total global emissions related to land-use change; most of these changes are caused by changes in land use for the production of food and fodder, or for other reasons (EC, 2009b). Searchinger and Heimlich (2015) report that a gradual phasing out of bioenergy production which uses crops or uses land would be a positive step towards a sustainable future for food production. Despite this, the farm acres devoted to different crops in the USA show that although corn acreage increased alongside the growth of the corn ethanol industry between 2004 and 2013, the USA's total main crop acreage has not changed significantly (Van den Bos and Hamelinck, 2014; Walancik and Chmiel, 2014). Taheripour and Tyner (2013) reported similar trends, also noting that crop shifting (e.g., fields growing wheat converted to production of corn) in the USA during this period was a key method of achieving additional corn production. Another method is probably bringing grasslands, wetlands, and other land into agricultural use.

The main point here, is that acreage devoted to agriculture in the USA has not seen any significant growth even though there has been a dramatic growth in biofuels. Furthermore, the US Renewable Fuel Standard stipulates that biofuel feedstocks must be sourced from land that had not been forested before 2007, which restricts the extension of agricultural land into forested lands to produce biofuels. For woody feedstocks, they must be derived from forests which were managed plantations before 2007. It is possible for a decline in deforestation and an increase in agricultural production to occur simultaneously at tropical forest frontiers, as long as there is sufficient land available and that there are policies in place to promote the efficient use of land that has already been cleared (intensification) while putting a brake on deforestation. It is still unclear whether government- and industry-led policies will be strong enough to restrict deforestation if market conditions at a future date are favourable for another dramatic increase in agricultural expansion (Macedo et al., 2012).

Academic studies using economic models have also found that biofuels can lead to reductions in lifecycle Greenhouse Gas (GHG) emissions relative to conventional fuels (Hertel et al., 2010; Huang et al., 2013). An advantage with second and third generation biofuels is that they have the potential to cause a reduction in GHG emissions when compared to conventional fuels because they enable feedstocks to be produced on marginal land. What is more, when considering waste biomass, there is no need for any additional agricultural production, and indirect market-mediated GHG emissions can be reduced to almost zero if no other productive use can be found for the waste. It is important to emphasise that the production and consumption of biofuels will not in itself cause any reduction in GHG or in conventional pollutant emissions. Nor will it reduce the need for petroleum imports, or reduce pressure on exhaustible resources. If we are to see any of these benefits, the production and use of biofuel must be accompanied with a reduction fossil fuel production and use.

The study, conducted by a consortium made up of IIASA, Ecofys and E4Tech on behalf of the European Commission, concludes that the increased demand for ethanol made from sugar and starch crops and cellulosic biomass will have significantly low impacts on Land Use Change (LUC) and low resultant emissions. The study also concludes that the resulting increased demand for sugar and starch crops from ethanol production will collectively have no impact on food prices by 2020 (Valin et al., 2015). Specifically, the study finds that conventional ethanol feedstocks, such as sugar and starch crops, have much lower land use change emissions impacts than other biofuel feedstocks. For example, in Europe the key feedstocks used to produce ethanol would have LUC emissions of 14g CO₂ e/MJ for maize, 15g CO₂ e/MJ for sugar beet and 34g CO₂ e/MJ for wheat. Cellulosic ethanol feedstocks similarly have a low or even positive LUC impact (16g CO₂ e/MJ for straw ethanol, 0g CO₂ e/MJ if a sustainable straw removal rate is introduced, and 12g CO₂ e/MJ and -29g CO₂ e/MJ for perennials and short rotation crops). Land use change impacts and associated emissions can be much lower if abandoned land (for example in the EU) is used for biofuels production; yield increases occur as a result of demand for biofuels, and/or peat drainage in Malaysia and Indonesia is halted. The study confirms that ethanol production has low LUC impacts, makes a strong contribution to reducing GHG emissions in the transport sector and has little or no effect on food prices. Another study by the University of Utrecht found that LUC-risks can be mitigated through agricultural yield increases and when unused land is used to grow crops

for biofuels production. Ethanol produced on these types of farmland has low-LUC impacts and strengthens our sector's contribution to environmental sustainability even further (Wicke et al., 2015).

The emergence of biofuel co-products can assist in reducing the impact of the environmental consequences of the growth of the bioethanol industry. The part played by feed co-products is quite significant in the USA, China, and the EU because of the large proportion of cereals which have high feed yields, although in Brazil it is much less, since ethanol production is predominately from sugarcane, a process which creates no feed co-products. DDGS, for example, can act as a substitute for maize and also for soybean meal in livestock feed. This means the land use impacts of biofuel production are lessened and the demand for fertilizers, pesticides and other chemical inputs are reduced in crop production. The fact that only the gross usage of maize for ethanol was reported meant that there was an assumption that maize produced for ethanol production was turned into fuel ethanol. However, the conventional assumption states that ethanol producers manage to return a third of the maize they process to the feeding sector. This represents the difference between the gross and net volume of the maize which is used for ethanol. In aggregate, in the USA one metric tonne of DDGS can, on average, substitute 1.22 metric tonnes of corn and soybean meal feed. The reality is that the amount of feed (i.e. maize and soybean meal) substituted by DDGS is 38% by weight of the maize consumed in the accompanying ethanol production process for any given crop year. Rapeseed is approximately 40% oil and 60% meal and soybeans are only 20% oil and 80% meal, reducing substantially the land use chemical input consequences of biodiesel production (Popp et al., 2014).

The ethanol industry produces worldwide an estimated 45 million metric tonnes of feed, including distiller's grains (90%) and gluten feed and gluten meal. About 7 million tonnes of soybean oil and 9 million tonnes of rapeseed oil is used in biodiesel production, contributing to almost 28 million tonnes of soybean meal and 13 million tonnes of rapeseed meal output. Taking into consideration that 210 million tonnes of soymeal, 40 million tonnes of rapeseed meal and 15 million tonnes of sunflower seed meal is produced globally every year, the co-products of biodiesel production have a relatively high impact on the feed market. The protein feed output by the biofuels industry is equal to about 65-70 million tonnes of soybean meal in protein equivalent, or 30% of the global soybean meal production (RFA, 2016; OECD/FAO, 2016).

At present approximately 2% of global cropland is devoted to biofuels (30-35 million gross hectares), and there are significant differences between countries and regions. Langeveld et al. (2014a) observed that there was 32 million ha of land used for biofuel production in 2010, which represented an increase of 25 million ha on the figure for 2000. The WBA (2015) reports that the figure for land devoted to biofuel production in 2013 was less than 30 million ha. The global yields of major crops of wheat, rice and corn have increased since 2000. If the same production of crops was required in 2013 with yields from 2000, 134 million ha additional land would be needed. Hence, productivity gains in agriculture based on better varieties, soil management, weed control, better education of farmers etc. had the same impact as 134 million ha (an extra 23%) of additional land. Models that ignore this innovation in agriculture come up with misleading results (WBA, 2015).

In theory, co-products are credited with the area of cropland equivalent to that needed to produce the feed they substitute. If we allow for co-products, there is a decline in the net use of feedstocks. If we include co-products substituted for grains and oilseeds, then the land that is needed to grow feedstocks reduces from a net requirement of about 2% of the total global crop area, to about 1.5%. It is a more difficult - but still important - task to calculate the impact of co-products on changes in land use change and on the GHG emissions accompanying the production of ethanol and biodiesel. When they evaluate the net GHG impacts of grain ethanol and biodiesel, the majority of biofuel regulations currently in force show a significant undervaluation of the contribution made by co-products. However, the inclusion of co-products when evaluating GHG is important, because they can have an impact on the overall emissions statistics. This kind of substitution causes a reduction in indirect land use and consequently a major reduction in the impact of changes in the use or intensification of indirect land use (Popp et al., 2014). In the future, using agricultural crops for biofuel will cause a minor increase in the cost of livestock feed, but this will, to some extent, be offset by the use of co-products for feed and also by growing crop yields over time. It is predicted that the output of feed co-products will increase at a slower rate in the coming years. However, it is possible that various new and emerging technologies will change the composition of feed co-products

and also bring further improvements in their nutritional quality and utility. It is likely that in coming years the ethanol co-products market will be transformed by new technologies and practices.

4. Transport biofuels in the EU

The EU has a relatively small share of world arable land, at 108 million ha. A modern bio-refinery uses only the starch (sugar) or oil content of the crop, such as corn or wheat, and the genuinely valuable nutritional components of the crop are returned to the food chain in the form of high protein animal feed. Note that sugar is the least valuable calorie that exists nutritionally. In 2014, the feedstocks used to produce ethanol in the EU were: maize (42%), wheat (33%), sugar beet (18%), and other cereals (7%). In the EU, the required feedstock for bioethanol production is estimated at 10 million tonnes of cereals and 11 million tonnes of sugar beets, accounting for about 3% of total EU cereal production and about 9% of total sugar beet production (ePURE, 2015). EU ethanol production utilises only 3% of EU grain supply or 1.8 million hectares (3% of the 58 million hectares of land under cereal production and only 9% of EU sugar substrate or 0.15 million hectares (sugar beet is harvested from about 1.6 million hectares).

Generating high-protein animal feed as a co-product of ethanol reduces land use for feedstocks by about 35% and also reduces the need for farmers to use imported animal feed, such as soybean and soymeal. For every tonne of cereals used by the ethanol industry as much animal feed is produced as ethanol. In 2014 around 3.3 million tonnes of highly valuable animal feed (DDG, wheat gluten and yeast concentrates) was produced in the EU, which displaced nearly 10% of soybean and soybean meal imports by volume. Reducing imports of animal feed improves the environmental footprint in the EU and helps reduce land conversion and GHG emissions resulting from agricultural land use outside of Europe. In addition, the overwhelming majority of agricultural crops used to produce ethanol are not suitable for direct human consumption (ePURE, 2015). If co-products are taken into account, the net land use for feedstock production declines to 1.3 million hectares (from 1.95 million hectares of gross land use).

Biodiesel is the most important biofuel in the EU and, on an energy basis, represents about 80% of the total transport biofuels market. Rapeseed oil is still the dominant biodiesel feedstock in the EU, accounting for 55% (6 million tonnes) of total production in 2014. Palm oil has become the second most important feedstock (1.6 million tonnes), mainly because of its use in the Neste Oil plants, developing a process of hydrogenation to produce Hydrotreated Vegetable Oils (HVO). Palm oil is followed by used cooking oil (1.7 million tonnes) due to the fact that some Member States have introduced double-counting. The use of soybean oil (0.9 million tonnes) and palm oil in conventional biodiesel is limited by the EU biodiesel standard. Sunflower oil (0.3 million tonnes) only comprised 3% of the total biodiesel feedstock. A constraint for biodiesel imports are the sustainability requirements laid down in the Renewable Energy Directive (RED). In 2014, around 5-6% (650 million litres) of the EU's biodiesel production was imported. Furthermore, about 1.5 million tonnes of vegetable oil is imported (palm oil, soybean oil, and to a lesser extent rapeseed oil) a year for biodiesel production (USDA, 2015). Biodiesel production today uses around 3 million hectares of arable land in the EU (EBB, 2016).

The extraction of vegetable oil from rapeseed, soybean and sunflower results in the production of seed meal co-products. A significant share of domestically produced biodiesel feedstock is crushed from imported oilseeds (soybeans and rapeseed). The 6 million tonnes of rapeseed oil feedstock used for biodiesel production is equivalent to about 15 million tonnes of rapeseed. This also generates about 9 million tonnes of rapeseed meal as co-product, most of which is used for animal feed. Similarly, the 0.9 million tonnes of soybean oil has to be crushed from 4.3 million tonnes of soybeans (mainly imported soybeans) generating about 3.4 million tonnes of soybean meal as co-product. In addition, about 0.8 million tonnes of sunflower is also used for biodiesel production with a co-production of 0.5 million tonnes of sunflower meal. The amount of oilseed meals as feed material in the compound feed industry reached 42 million tonnes in 2014 and the contribution of the biodiesel industry accounted for over 30% (FEFAC, 2015). If co-products are taken into account (mainly rapeseed meal), the net land use for feedstock production declines to 1.4 million hectares (from 3.0 million hectares of gross land use).

Animal feed co-production in biofuel plants saved the equivalent of 3.2 million ha of crop production in the EU in 2010. Bioenergy is fundamentally an agricultural industry. Bio-refineries produce equal amounts of animal feed and biofuel. This animal feed has a very high protein content and ensures that none of the feed content of crops is lost in the refining process. It also contributes to reducing Europe's considerable animal feed deficit, reducing imports of feed from deforesting areas (e.g. soy from Brazil) and reducing the amount of land needed to grow animal feed (Langeveld et al., 2014b). Since the RED was passed, more agricultural land has been removed from productive use than would be needed to supply all of Europe's biofuel plants. No land in Europe has been removed from food production for first generation biofuels (Langeveld et al., 2014b). This statement is in line with other studies about land use for feedstock production. The total area of land required to grow the feedstock needed in 2010 was 5.7 million hectares. Of this, 3.2 million hectares (57%) was within the EU and 2.4 million hectares (43%) outside (Ecofys, 2013; Allen et al., 2014). For example, a conservative estimate of an additional 1.73 - 1.87 million hectares of global cropland could be needed in 2020 in order to fulfil EU biofuel targets (Laborde, 2011). Our calculation shows at present a gross land usage of around 5.0 million hectares. However, the land use effect is lower when co-products are sent to the animal feed market, because this leads to a decrease in net land use of 2.7 million hectares.

5. Renewable Fuel Standard and Renewable Energy Directive

In the US the Energy Independence and Security Act (EISA) stipulates four quantitative annual mandates up to 2022: the advanced mandate also includes the biodiesel and the cellulosic mandates, as well as the total mandates which state that fuel production should manage to reduce GHG by 20%, 50% and 60% respectively. A fuel must achieve at least 50% GHG reduction to be considered an "advanced biofuel," at least a 60% reduction to be considered a "cellulosic biofuel," and at least a 50% reduction to be considered "biomass based diesel." Similarly, biofuel from new facilities must achieve at least a 20% GHG reduction to qualify as a generic renewable fuel. The advanced mandates are defined by eligible feedstock types and lifecycle GHG emission reductions. Biofuel that does not qualify for these specific mandates can still count toward the overall Renewable Fuel Standard (RFS). The potential annual amounts of biofuel in this last category are not specified explicitly in EISA, but are derived as the residual from the total RFS and the advanced biofuel mandates. This residual category is frequently referred to as the "non-advanced" mandate or the "conventional" mandate and has typically been met with corn-starch based ethanol (EPA, 2013). The RFS caps maize ethanol volumes at 15 billion gallons (around 130-140 million tonnes of maize used, as feedstock accounting for 35-40% of total US maize production a year).

The general assumption is that the advanced mandate will be expanded in the next decade, since there are likely to be lower prospects for gasoline use and a more limited availability of blends below the 10% blend wall; consequently, it is believed that the corn based ethanol mandate will also fall after 2018. There will be an increase in the biodiesel mandate, given that biodiesel – similarly to sugarcane based ethanol – is included under the advanced mandate. Argentinean soybean oil based biodiesel has received certification, which will allow it to fulfil both the biodiesel and the advanced mandates. However, it is predicted that over the next few years there will be a lower requirement for the advanced gap to be filled by sugarcane based ethanol imports. By 2025 only about 2% of the EISA specified cellulosic mandate will be filled; this is due to shortages, and also to the fact that the difference currently existing between the EISA cellulosic mandate and the assumed mandate will disappear. The likelihood is that this mandate will be filled by renewable compressed natural gas and renewable liquefied natural gas (USDA, 2016).

Within the EU, biofuels policy is governed by the 2009 Renewable Energy Directive, which stipulates that renewable fuels (including non-liquid fuels) should make up 10% of all transport fuels by 2020, as measured in energy equivalents. There is also the Fuel Quality Directive (FQD), which stipulates that fuel producers must achieve a 6% reduction in transport fuels' GHG intensity by 2020; it also controls the sustainability of biofuels. The EU Energy and Climate Change Package (CCP) was adopted by the European Council on April 6, 2009. The RED, which is part of this package, entered into force on June 25, 2009, and had to be transposed into national legislation in all Member States by December 5 2010. The RED requires that renewable fuels (including

non-liquid fuels) make up 10% of total transport fuel use by 2020, as measured in energy equivalents, because this is the sector which is seeing the fastest increase in GHG emissions (EC, 2009a; EC 2009b).

The wider target is for clean energy to make up 20% of fuel used in transport, power stations, heating stations, and cooling stations combined. The CCP includes the “20/20/20” goals for 2020, namely a 20% reduction in GHG emissions compared to 1990, a 20% improvement in energy efficiency compared to forecasts for 2020 and a 20% share for renewable energy in the EU total energy mix. Part of this 20% share is a 10% minimum target for renewable energy consumed by the transport sector, to be achieved by all Member States. In September 2015 both of these directives (RED, FQD) were amended by a new Directive, known as the “Indirect Land Use Changes” (ILUC) Directive; this introduced a 7% cap on the amount of renewable energy in the transport sector deriving from food and feed crops. The main elements of this Directive regulating the ILUC of biofuels (EU, 2015):

- Limitation to 7% of the contribution of conventional biofuels for 2020.
- Obligation of the Member States to establish indicative national targets for advanced biofuels for 2020, with a reference value of 0.5%, which Member States can lower for objective reasons.
- Double counting of all the biofuels produced from raw materials included in the new annex of renewable energies, including used cooking oil and animal fats.
- Increase in the multiplier factors of electricity produced from renewable energy sources consumed by electric road vehicles (from 2.5 to 5) and rail transport (from 1 to 2.5) for the calculation of the market share of renewables in transport. These multiplication factors range between 1 and 2.5 with energy used for electrified rail transport, and between 2.5 and 5 with renewable electricity used in road transport.
- Obligation of fuel suppliers to report annually the provisional mean values of the estimated indirect land-use change emissions from biofuels traded, with the information to be sent to the Member States annually.
- Increase in the minimum reduction threshold of greenhouse gas (GHG) emissions applying to biofuels and bioliquids produced in new installations (GHG emissions saving from the use of biofuels shall be at least 60% for biofuels produced in installations starting operation after 5 October 2015. In the case of installations that were in operation on or before 5 October 2015, biofuels shall achieve a GHG emission saving of at least 35 % until 31 December 2017 and at least 50 % from 1 January 2018).

On the basis of the RED progress reports for Member States, an overview was made showing consumption of double-counting biofuels (i.e. biofuels deriving from waste and residues) in each Member State. There are four Member States, namely the Netherlands, Italy, the UK and Germany which mainly account for double-counting biofuel consumption. In 2012 these countries consumed 70% of these biofuels, most of which were produced from UCO and animal fat. This contributed to an overall EU average of 15% in 2012 (Pelkmans et al., 2014). Given that a high proportion of double-counting biofuels means a more limited proportion of food-based biofuels, the introduction of the 7% cap allow further notable growth in food-based biofuels in these countries over the next few years (Figure 4). The OECD has predicted that with blending of first generation biofuels, the energy equivalents in overall gasoline and diesel use will remain below the 7% cap, i.e. at 6.3% by 2020. This includes advanced biofuels derived from used cooking oil and from tallow, which in terms of the Directive are classified as double counting fuels. Any further move towards the RED target should be linked to the development of other energy sources for the transport sector, including electric cars (OECD/FAO, 2016).

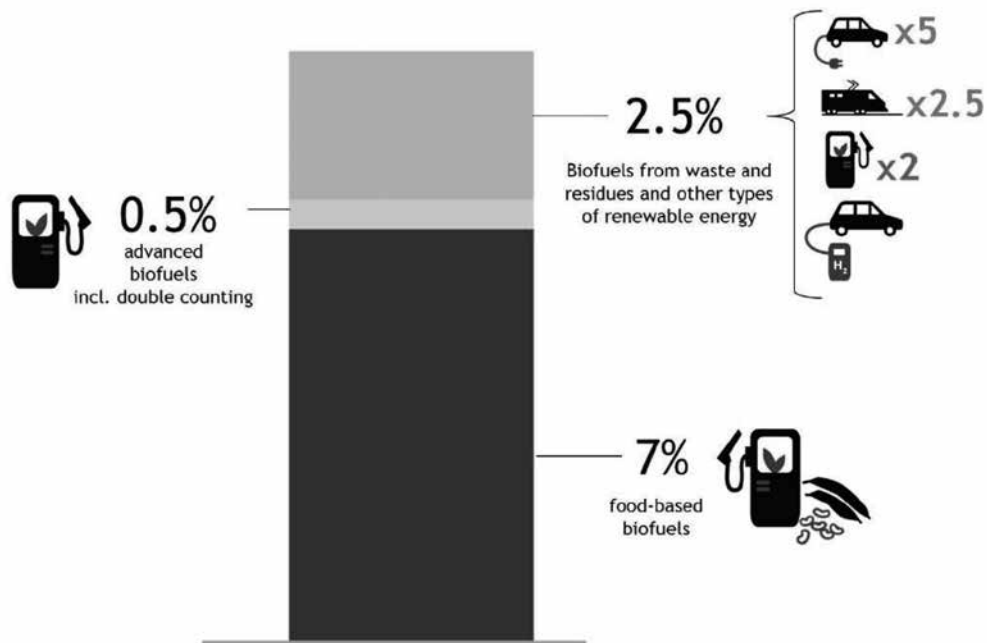


Fig. 4. Ways in which the 10% target can be achieved, in accordance with the ILUC Directive

Source: van Grinsven and Kampman (2015)

According to the Renewable Energy Report in 2016, the prospects for achieving the 20% renewable energy target by 2020 are good; however, some Member States had difficulties in achieving their targets. In 2015, the projected share of renewable energy in gross final energy consumption was 16,7%. The report also found that achieving the 10% target for renewable energy in transport is challenging, but feasible with the development of advanced biofuels. The average share of renewable energy sources in transport fuel consumption across the EU-28 was 6,7% in 2014, ranging from highs of 11,4 in Austria, 22% in Finland and 24% in Sweden (the only Member States with double-digit shares) to less than 1.0% in Estonia. It is estimated that transport represents over 30% of final energy consumption in Europe and that 94% of transport relies on oil products; therefore, an effort towards increased use of renewables in the transport sector must be ambitious, with a clear link to the decarbonisation of the transport sector (Eurostat, 2017).

The only biofuels which can be included in the 10% target are those that meet the sustainability criteria for biofuels and bioliquids as described in the RED. Low oil prices and poor margins continue to challenge biofuel producers in Europe. Under current market conditions it is unlikely that the 7% cap will be reached in the EU by 2020. Over the past five years, production of biodiesel from waste and animal fats has taken off, while the commercialization of cellulosic ethanol is lagging behind compared to this development (OECD/FAO, 2016). It is possible for Member States to reduce the incentives they offer for biofuels (e.g. reduce the required level of biofuels) as a response to the higher multiplication values associated with renewable electricity. However, they can also attempt to achieve a level of renewable energy sources in the transport sector higher than the 10% target.

5.1. Capping food-based biofuels: the relationship between the ILUC Directive and FQD targets

Member States must require suppliers of fuel to achieve reductions of up to 10% (a mandatory 6%) in the life cycle GHG emissions per unit of energy in the fuels they supply compared with the fuel baseline (i.e. the 2010 figure). Given a reduction in the average GHG intensity of biofuels following the Indirect Land Use Change (ILUC) Directive, in theory it should be easier to meet the Fuel Quality Directive (FQD) target. However, it is important to bear in mind that the biofuel volume required to meet the 10% RED target will be reduced because of the increased multiplication factor for renewable electricity in the rail and road transport sector, also given the growing application of double-counting biofuels. In practical terms this could result in a reduction of the con-

tribution made by the RED policy in achieving the FQD target (for which double-counting cannot be applied), which means that extra efforts will probably be needed in order to meet the 6% GHG intensity reduction target by 2020. Here, we should also point out that a difference exists between the way the various directives – the ILUC Directive, the RED and the FQD – are implemented. With the RED Member States are required to assume direct responsibility for targets; the FQD, on the other hand, obliges Member States to require fuel suppliers to meet the FQD target themselves. In practical terms this implies that a Member State which had correctly implemented the FQD would not be accountable if the targets themselves were, nevertheless, not achieved. It is not possible to show the current progress of the FQD towards the 6% GHG reduction target because of a lack of data – there is no monitoring nor reporting of GHG intensity data at the EU level (van Grinsven and Kampman, 2015).

The only Member States which are currently pondering a lower cap are those which have high proportions of double-counting biofuels and, consequently, relatively low proportions of food-based biofuels. In order to increase biofuel consumption levels, the majority of Member States have brought in a renewable energy mandate which requires fuel suppliers to include a defined proportion of biofuels (or other renewable energy types) in their overall fuel sales. It is thought that these mandates will assist in guaranteeing that there will be higher consumption of biofuels, so as to meet the 10% RED target in 2020, and simultaneously help reach the 6% FQD reduction target. The real proportion of biofuels by volume might be lower given the administrative contribution of biofuels from waste and residues (i.e. allowing for double counting and multiplication factors). In the case of both France and Sweden their biodiesel quota is above the 7% blending limit, but it is important to note that these quotas can in part be achieved by administrative techniques, such as double-counting biofuels and/or by using drop-in biofuels, such as HVO. Member States have, usually, preferred to stay close to their current level of food-based biofuels, so that those states which have relatively low proportions of these biofuels usually choose to implement lower caps. France has already introduced a provision equivalent to a cap in the national biofuel mandate: its present biofuel mandate stipulates a proportion of biodiesel of 7.7%, of which at least 0.7% should be made up of double-counting biofuels. The only Member State which operates a sub-target is Italy (2% ligno-cellulosic materials, effective from 2018 onwards, although this was the result of a political decision taken in 2014). Based on the case studies above, Italy appears to be the only Member State aiming for a higher sub-target than the 0.5% indicated. As regards the sub-target for advanced biofuels, EU states are at present dealing with two problems: developing appropriate production capacity and handling the sustainability risks which accompany the feedstocks used to produce these biofuels (van Grinsven and Kampman, 2015).

So far, the majority of Member States have concentrated on achieving the RED target, adopting biofuel policy measures to meet the 10% target. Because of their strong biofuel policies, Sweden and Finland will probably be able to achieve the 6% FQD target without any extra policy measures; other Member States, however, may well need to implement measures to reach the target, and some are indeed researching various options. Although biofuels will be the main element in achieving the 6%, there will also be a need for upstream emissions reduction. Member States believe that the efforts needed to achieve implementation will be significant when compared to the expected role of Upstream Emission Reductions (UER). It is probable that UER will only make a minor contribution to the 6% target. There is a view, expressed by some Member States, that the UER contribution should not be excessive, because this might jeopardise achievement of the 10% target.

All Member States are searching for opportunities to grow their domestic markets; however, most analyses of biofuel production capacity are also alert to import possibilities. Funding from the EU offers ways to increase advanced biofuel production, but any fiscal or financial incentives to encourage advanced biofuel production will not be introduced in time to yield results before 2020: a decision on ILUC was delayed, which had the knock-on effect of ensuring a low level of investment certainty in the biofuel industry over the last few years, and as a consequence not many investments have been made. It is true that the ILUC decision could act as a trigger to scale up these technologies; however, the ILUC Directive is only effective between 2017 and 2020 and many advanced biofuel pathways still remain at a research and development stage, so EU states will probably gain more from such investments after, rather than before, 2020. Those decisions which affect the period following 2020 are likely to offer stronger incentives. In addition, it should be mentioned that investments made in the next three years are not very likely to help increase the proportion of advanced biofuels until 2020.

6. Competition between conventional and advanced biofuels

According to Searchinger and Heimlich (2015), the dedicated use of land for bioenergy can be defined as any production of bioenergy which involves the sacrifice of alternative outputs from the land used. This is a somewhat restricted definition which considers bioenergy production as an isolated phenomenon. For example, there are some feedstocks (such as soybeans and rapeseed) grown for biofuel which cannot be defined in this way because the main product is protein in the form of animal meal and the secondary product is oil (this can include cooking oil, or a biofuel feedstock, as biofuel products). In this scenario biofuel production derived from oil does not represent a dedicated use of land for bioenergy production. In fact, the authors in no way supported bioenergy production from these types of feedstocks. Furthermore, "land" is a wide-ranging term which covers many varied types in terms of productivity and suitability for different types of vegetation. Areas of land that might not be appropriate for raw crops may well be right for other types of vegetation because of variations in nutrients, water, climate, and other requirements. It is also worth mentioning that the authors considered marginal/degraded lands as non-existent (Wang and Dunn, 2015).

Searchinger and Heimlich (2015) were correct to note that using wastes such as crop residues and urban solid waste to create biofuel products is an appropriate way to use these resources. They were worried, however, that dedicated cellulosic crops do not constitute a good source of biofuel feedstock given that they need land and do not produce sufficiently high yields. Some related studies have indeed shown that it is possible to achieve a doubling of the currently low cellulosic biomass yields (Lynd et al., 2009). Furthermore, it can be reliably stated that there are extensive areas of currently underutilized marginal land where cellulosic crops could be produced (Cai et al., 2011). Many studies have succeeded in identifying land which could be used to grow cellulosic biomass so that competition between cellulosic biomass and food production could be avoided (Perlack et al., 2011; Werling et al., 2014).

Conclusions

Energy consumption is still increasing rapidly, with an approximate 570 EJ consumed at the primary energy level in 2014. The world gets about 19.2% of its energy from renewables, including about 8.9% from traditional biomass and about 10.3% from modern renewables. Traditional solid biomass and hydroelectricity still dominate renewable energy consumption on a global scale. Currently, the amount of renewable energy consumed globally is about 76 EJ/year. In 2014, investments in solar and wind energy together accounted for 92% of the total global renewable energy source investments. Biofuels experienced a steady growth in new investment from 2004 to 2007, but after 2008 investments in biofuels started to decline and fluctuate at lower levels due to uncertainties over future legislation, delayed development of second generation biofuels and relatively high costs. Recent estimates on the potential global ligno-cellulosic bioenergy supply for 2050 range from less than 100 EJ/year to 1 500 EJ year. In other energy scenarios, bioenergy use is projected to be in the order of 150-400 EJ in the year 2100. 28% of world final energy consumption is accounted for by the transport sector, and transport sector biofuels are at the moment the fastest growing bioenergy sector, even though they still only make up around 3-4% of total road transport fuel and 5% of total bioenergy consumption. By 2015 the EU-28's proportion of renewable energy had grown to 15.2% and so had already passed the target level.

The area currently creating most interest is liquid biofuels for transport, even though only a tiny proportion of biomass is currently used globally for biofuels production. Liquid biofuels continue to make a small but growing contribution to transport fuel demand worldwide, currently providing about 3-4% of global road transport fuels and around 5% (3.5 EJ/year) of bioenergy. At the moment, ethanol accounts for about 80% of global production of liquid biofuels, and in 2015 global production of fuel ethanol was 116 billion litres, with the figure for global biodiesel production being 31 billion litres. Coarse grains, sugarcane and molasses will remain the dominant ethanol feedstock and vegetable oil the feedstock in biodiesel production. By 2025, 22% of global sugarcane, 0-11% of global coarse grains and 12% of global vegetable oil production is expected to be used to produce biofuels. Ligno-cellulosic biomass based ethanol is projected to account for less than 1% of world ethanol production. Biodiesel production based on non-agricultural feedstock and in particular waste oil and tallow will develop in the EU and the United States.

The possible impact of developed countries' biofuels policies on global food prices became a significant concern in 2007, when global grain prices reached historic heights. The recent World Bank report concludes that increases in oil prices, changes in stocks and exchange rates, and not biofuel expansion, were the reasons for agricultural commodity price increases since 2004. This is a clear indication of a decoupling of biofuel production growth, which has increased steadily over the past decade. Furthermore, the RFS in the US caps maize ethanol volumes at 15 billion gallons (around 130-140 million tonnes of maize use as feedstock). In the EU new legislation limits the contribution of biofuels derived from sugars, starch, and oil crops to 7% due to sustainability concerns, which are mainly related to indirect land-use change. Biofuel co-products often substitute for higher priced feeds in animal rations. The increased use of agricultural commodities for biofuels has led to higher costs for animal feeds; however, increased substitution of co-products for traditional feedstuffs in feed rations mitigates the input cost increases faced by livestock and poultry producers.

Currently some 2% (30-35 million gross hectares) of global cropland is devoted to biofuels. The co-products deriving from the biofuel industry mean that there is a reduced impact of biofuel production in terms of land use, and the demand for chemical inputs, such as fertilizers and pesticides in crop production is also reduced. Co-products should be credited with an equivalent area of cropland needed to produce the amount of feed that they replace. If we add in the co-products which are substituted for grains and oilseeds, then we find that the land needed to grow feedstocks decreases from about 2% to 1.5% of the global crop area. Another equally important consideration is the impact of co-products on changes in land use and on the GHG emissions which accompany the production of ethanol and biodiesel. The truth is that when evaluating the net GHG impacts of grain ethanol and biodiesel, the majority of existing biofuel regulations significantly underestimate the contribution which co-products make.

In the EU the gross land usage for biofuel production is around 5% of total arable land or 5.0 million hectares. However, land use effect is lower when co-products are sent to the animal feed market, because this leads to a decrease in net land use of 2.7 million hectares. Animal feed co-production in biofuel plants saved the equivalent of 3.2 million ha of crop production in the EU. Since the RED was passed, more agricultural land has been removed from productive use than would be needed to supply all of Europe's biofuel plants. No land in Europe has been removed from food production for first generation biofuels. The prospects for achieving the 20% renewable energy target by 2020 are good; however, some Member States had difficulties in achieving their targets. In 2014, the projected share of renewable energy in the gross final energy consumption was 15.3%. Achieving the 10% target for renewable energy in transport is challenging, but feasible with the development of advanced biofuels. The average share of renewable energy sources in transport fuel consumption across the EU-28 was 5.9% in 2014.

It was concluded that increases in oil prices, changes in stocks and exchange rates, and not biofuel expansion, were the reasons for agricultural commodity price increases since 2004, indicating a decoupling of biofuel production growth. In addition, the US caps maize ethanol volumes at 15 billion gallons or around 130-140 million tonnes of maize use as feedstock and in the EU new legislation limits the contribution of biofuels coming from food and feed crops to 7%. Several studies confirm that ethanol production has low LUC impacts, makes a strong contribution to reducing GHG emissions in the transport sector and has little or no effect on food prices. To date, we have witnessed only limited economic and environmental implications related to biofuel production; however, in the future using wastes products such as crop residues and urban solid waste for biofuel production would be a good use of these resources.

Low oil prices and capping food-based biofuels continue to challenge biofuel producers in Europe. It is unlikely that the 7% cap will be reached in the EU by 2020. In the last couple of years, production of biodiesel from waste and animal fats has increased, while the commercialization of cellulosic ethanol is lagging behind compared to former targets. If co-products are credited with the area of cropland required to produce the amount of feed they substitute, the net use of feedstocks decline. Furthermore, co-products are supposed to be included in GHG assessment because of their potential impact on the overall emissions. Most existing biofuel regulations significantly undervalue the contribution of co-products when assessing the net land use and GHG

impacts of biofuel production. Long-term transport shares are the most challenging to project because the range of possible vehicle technologies and fuel types in the future is very broad and future oil prices are uncertain. It is concluded that the rise in the use of biofuels has slowed down and sustainability criteria have been established regarding the use of land and the mitigation of environmental impacts caused by biofuel production.

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