SUSTAINABLE LIQUID BIOFUELS (BIOETHANOL, BIODIESEL) PRODUCTION AND THEIR MULTIFUNCTIONAL IMPACTS

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Abstract

The share of fossil energy (oil, coal, natural gas) in final energy consumption was 79.7% in 2019, renewable energy 18.1% and nuclear energy 2.2% worldwide. Renewable energy is the world's fourth largest source of energy after oil, coal and natural gas, of which "modern" renewables account for 10.6% (wind, solar, hydro, geothermal, biofuels, etc.); traditinal biomass represents 7.5%. Including traditional and modern renewable uses of biomass, bioenergy has contributed 12.7% to the global energy supply. The global spread of biofuel production has provoked serious debate, especially on environmental and social sustainability issues such as its impact on food production, land use change, biodiversity, energy efficiency and climate change. The complexity of economic, social and environmental problems asumes a holistic perspective to reap the benefits of the potential synergy effect. The sustainability of biofuels is, in fact, about optimization between the economic, social and environmental dimensions.

Keywords: *biofuel, bioethanol, biodiesel, sustainability*

FENNTARTHATÓ FOLYÉKONY BIOÜZEMANYAG (BIOETANOL, BIODÍZEL) ELŐÁLLÍTÁSA ÉS MULTIFUNKCIONÁLIS HATÁSA

Összefoglalás

A végső energiafogyasztásban a fosszilis energia (kőolaj, szén, földgáz) aránya 2019-ben az 79,7%-ot, a megújuló energiaforrások 18,1%-ot és a nukleáris energia 2,2%-ot tett ki világszerte. A megújuló energia a világ negyedik legnagyobb energiaforrását jelenti a kőolaj, szén és földgáz után, ebből a „modern” megújulók 10,6%-ot (szél-, nap-, víz-, geotermikus-energia, bioüzemanyagok stb.), a tradicionális biomassza 7,5%-ot képvisel. A biomassza hagyományos és modern megújuló felhasználását is beleértve, a bioenergia 12,7%-kal járult hozzá a globális energiaellátáshoz. A bioüzemanyaggyártás globális terjedése komoly vitákat váltott ki, elsősorban a környezeti és társadalmi fenntarthatóság kérdésében, mint például az élelmiszertermelésre, a földhasználat változására, a biodiverzitásra, az energiahatékonyságra és az éghajlatváltozásra gyakorolt hatása. A gazdasági, társadalmi és környezeti problémák összetettsége holisztikus perspektívát feltételez a potenciális szinergia hatás előnyeinek érvényesítése érdekében. A bioüzemanyagok fenntarthatósága tulajdonképpen a gazdasági, társadalmi és környezeti dimenziók közötti optimalizálásról szól.

Kulcsszavak: *bioüzemanyag, bioetanol, biodízel, fenntarthatóság*

JEL kód: *Q41, Q42, Q43*

Introduction

Energy consumption is still increasing. In 2016, the global total primary energy supply was 576 exajoules (EJ). Roughly 31% of primary energy consumption goes to losses through the demand of the energy industry and different transformation transmission and distribution processes. The global final energy consumption was 400 EJ in 2016. The transport sector uses one third of total final energy demand and is responsible for 23% of global energy-related CO_2 emissions, which rose by 1.6% in 2017 and continued growth is expected in the future (IEA, 2018). About 96% of global transport energy needs are met by oil and petroleum products, the rest by electricity and biogas (REN21, 2019), therefore increased use of renewables in the transport sector has high priority in the decarbonisation of the transport sector.

The renewable energy sector employes 11 million people worldwide. In 2017, renewable energy accounted for an estimated 18.1% of total final energy consumption. Bioenergy – as solid, liquid or gaseous fuels – provides roughly 50% of the energy derived from renewable sources. Bioenergy in mainly used for heat and transport. Other renewables (e.g., solar, wind etc.) have less penetration in the heat and transport sectors accounting for 80% of total final energy consumption. Traditional use of biomass for cooking and heating accounts for 7.5% and modern renewables for 10.6% in total final energy demand. In the past, biomass was based on 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 to aquatic biomass. The traditional use of biomass has been stable over the last years but its share in global final energy supply has been gradually declining while the "modern" share has been growing since the late 1990s. The share of thermal energy was 4.2%, followed by hydropower (3.6%), wind, solar, biomass, geothermal and ocean power (2%), and transport biofuels (1%) in the modern renewable energy production (Figure 1). Including the traditional and modern use of biomass bioenergy contributed 12.4% to global energy supply in 2017 (IEA, 2018; REN21, 2019).

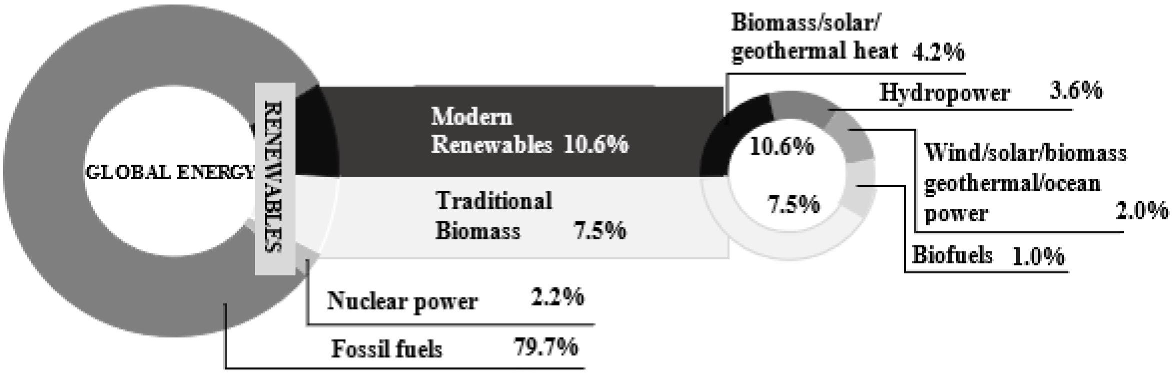

Figure 1. Estimated renewable energy share of global final energy consumption in 2017
Source: REN21 (2019)

Currently, around 77% of the global production of liquid biofuels is in the form of ethanol. Global fuel ethanol production increased to 112 billion litres on average during the period of 2016-2018. Global ethanol production is projected to increase to 143 billion litres by 2028 (OECD/FAO, 2019). The US is the world's top ethanol producers, the United States and Brazil, accounted for around 84% of total production. Global expansion of biofuel production is projected to continue during the next decade, although at a slower pace than over the last decade.

The US is expected to remain the major ethanol producer and exporter, followed by Brazil. Fuel ethanol production in the US reached 61 billion litres, of which amount 11% was exported. In Brazil, ethanol production increased to 29 billion litres on average during 2016-2018. China, et 9.6 billion litres, remained Asia's largest ethanol producer. In the EU-28, ethanol production for fuel was 7.5 billion litres on average during 2016-2018. India with an ethanol production of 2.4 billion litres and Canada with a production of 1.9 billion litres remain significant producers of ethanol (Figure 2).

Global production of biodiesel reached 37 billion litres on average during the period of 2016-2018, of which HVO biodiesel made up 6 billion litres. Global biodiesel is forecasted to reach 44 billion litres by 2028 driven mainly by the mandate increase in the US. The expansion of global biodiesel production will be driven by biofuels policies in place in the USA, EU, Brazil, Indonesia and Argentina. Biodiesel production is far less concentrated than ethanol. The European Union remained the centre of global biodiesel production, with 13.5 billion litres representing 36% of total output, followed by the US and Brazil with 6.9 and 4.5 billion litres biodiesel output, respectively. Biodiesel production in the EU decreased due to fierce competition from biodiesel imported from Argentina and Indonesia. In Indonesia production grew to 3.7 billion litres but in Argentina production fell to 2.7 billion litres due to the introduction of US anti-dumping duties on biodiesel imports (Figure 3). Global ethanol production is projected to increase to 143 billion litres by 2028, while global biodiesel is forecasted to reach 44 billion litres by 2028 driven mainly by the mandate increase in the US. The EU will remain to be the major producer of biodiesel and other significant players are the US, Brazil, Indonesia and Argentina. Biodiesel consumption in the EU is projected to fall due to decreasing diesel consumption. Biodiesel production in the US is expected to increase to meet the biodiesel mandate and more broadly the advanced mandate. Brazil is expected to maintain its position as the third largest biodiesel producer. Biodiesel production in Indonesia will mainly serve to satisfy the increasing domestic blending requirements (OECD/FAO, 2019).

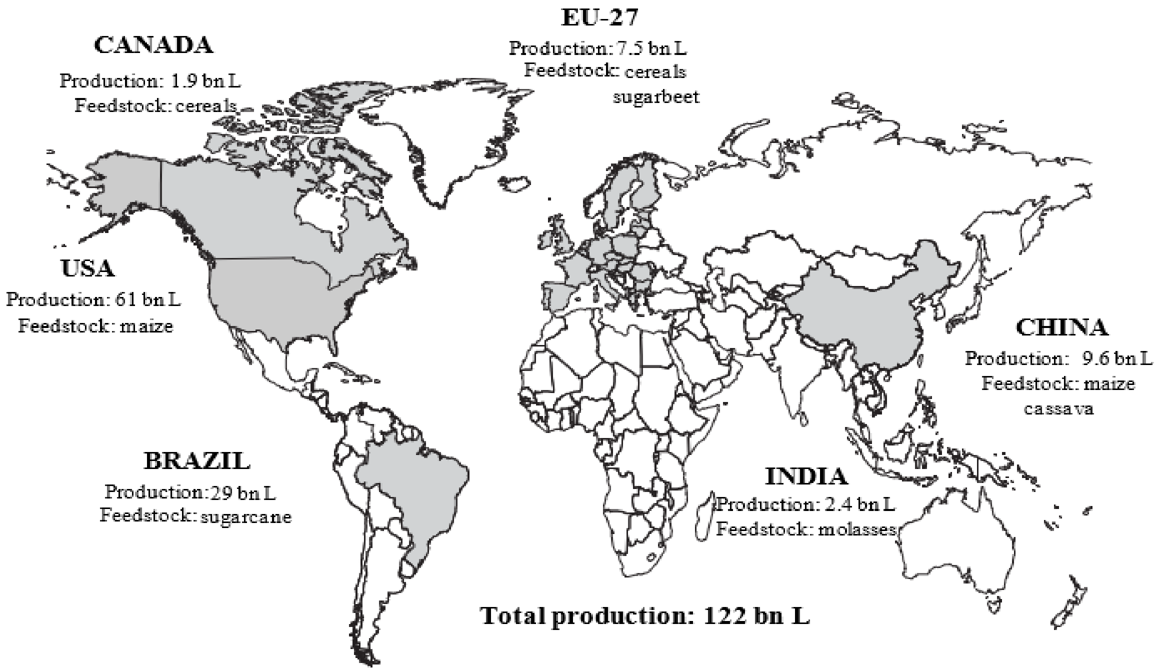

Figure 2. Word fuel ethanol production (average 2016-2018)
Source: OECD/FAO (2019); REN21 (2019)

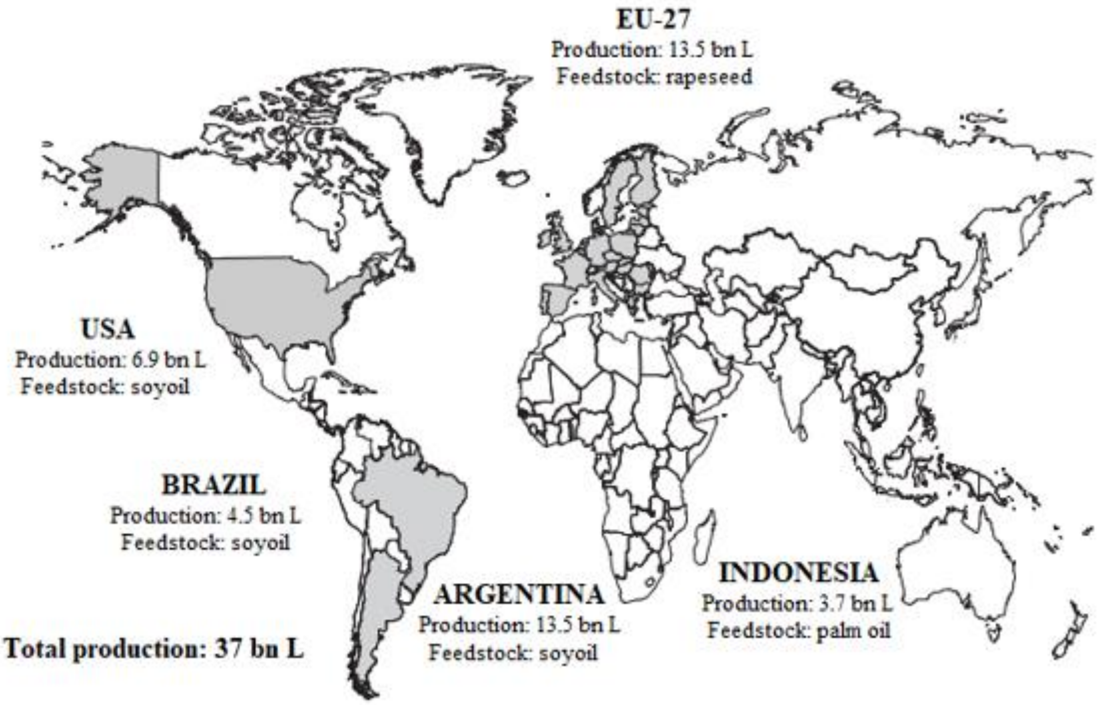

Figure 3. Word biodiesel production (average 2016-2018)
Source: OECD/FAO (2019); REN21 (2019)

Renewable energy use in the transport sector is still low with a share of 3.0% biofuels and 0.3% renewable electricity acconting for 3.5 EJ/year. The share of biofuels in total renewables used in the transport sector is still 90% despite the rapid expansion of electric cars. The share of electricity used for transport is 1.1% of final energy demand, of which 0.3% is renewable and 0.8% non-renewable electricity (IEA, 2018; REN21, 2019). The share of biofuels in the transport sector surpass 10% only in Brazil. International trade in biofuels has become much more important recently but will remain limited. Global trade for biodiesel and ethanol has rarely exceeded 10% share of total production and is concentrated in a few countries. Global ethanol trade is projected to remain as a low share of global production, decreasing from 9% over the base period to 8% by 2028. The US is expected to remain a net exporter of maize-based ethanol and a modest importer of sugarcane-based ethanol related to the advanced mandate and the Low Carbon Fuel Standard in place in California (OECD/FAO, 2019).

Coarse grains, sugarcane and molasses (in India) will remain the main ethanol feedstock and vegetable oil the feedstock in biodiesel production. About 60% of ethanol is produced from maize, 25% from sugarcane, 7% from molasses and the remainder from other grains, cassava and sugar beets. Almost all US production of ethanol uses maize as a feedstock accounting for a third of total US maize use. About 80% of biodiesel is based on vegetable oils and 20% on waste cooking oils and animal fats. Roughly 20% of global sugarcane and 10-11% of global coarse grains production is used to produce ethanol. Biodiesel production consumes 11-12% of global vegetable oil production. Recently production of biodiesel from waste oil and animal fats has grown in the EU, Canada and the US, while the market introduction of cellulosic ethanol is lagging behind compared to this development (OECD/FAO, 2019).

The international biofuel sectors are strongly influenced by national policies with three major goals: farmer support, reduced greenhouse gas emissions, and reduced energy independency. More advanced technologies based on cellulosic feedstocks do not account for large shares of total biofuel production, however, they are projected to reduce competition with food products and cut down greenhouse gas emissions. A huge number of countries have blending mandates of biofuels in transport. Nevertheless, long-term biofuels shares are uncertain because the range of possible vehicle technologies and fuel types in the future is very broad, future oil prices are uncertain, and technology progress from vehicle batteries to advanced biofuels, remains unpredictable (IEA, 2018). Biofuels have a limited ability to replace fossil fuels, however, they will reduce dependency on fossil fuels in the transport sector and moderate oil prices.

The proportion of global cropland used for biofuels is currently some 2% (30-35 million gross hectares) with wide differences among countries and regions. In the review by LANGEVELD et al. (2014) land devoted to biofuel production was calculated at 32 million ha in 2010. According to WBA (2015) land use for biofuel production was less than 30 million ha in 2013. Biofuel represents a very small percentage of overall changes in land use. It should be noted that for some crops biofuel demand accounts for a significant share of total demand (e.g. maize, oilseeds, sugarcane). The global yields of coarse grains have increased since 2000 due to productivity gains in agriculture based on better varieties, soil management, weed control, better education of farmers etc. By adding co-products substituted for grains and oilseeds the land required for cultivation of feedstocks declines from about 2% to 1.5% net land requirement of the global crop area (POPP et al., 2014).

The contribution of feed co-products is relatively high in the USA, China, and the EU due to the large share of cereals in the ethanol industry with high feed yields (DDGS). It is low in Brazil where ethanol production is dominated by sugarcane which generates no feed co-products. The main co-product of the biodiesel production is soybean meal and rapeseed meal. The protein feed output by the biofuels industry is equal to about 30% of the global soybean meal production. Biofuel co-products help mitigate the environmental consequences of expansion by the biofuel industry. This reduces the land use consequences of biofuel production and the indirect land use and therefore the impact of indirect land use change and intensification (less demand for chemical inputs) substantially Feed co-product output is expected to grow more slowly in the coming years (OECD/FAO, 2019).

The dependency rate of oil and gas import in the EU is today 55%. In 2017, renewable energy represented 17.5% of energy consumed in the EU surpassing the target level. The average share of energy from renewable sources in transport increased from 1.4 % in 2004 to 7.6 % in 2017 and is on track to meet its renewable energy target of 10% in the transport sector by 2020. It should be noted that the relative share of renewable energy in transport fuel consumption ranged from 39% in Sweden, 19% in Finland, 10% in Austria and 7% in Hungary to less than 2.0% in Croatia, Greece and Estonia (EUROSTAT, 2019a; EUROSTAT 2019b).

Biofuels produced in the EU rely largely on domestic feedstock. Rapeseed oil is still the dominant biodiesel feedstock in the EU, followed by UCO and palm oil. The share of rapeseed has decreased due to higher use of UCO and the double-counting system introduced for UCO by some Member States. Animal fats are less important feedstocks then UCO because just a few member states allow double-counting for animal fat. Palm oil is the third most important feedstock mainly because of its use for hydrogenated vegetable oils (HVO) production and competitive price. HVO are also considered advanced biofuels as they can fully replace fossil fuels in a mix (drop-in fuels), but are not necessarily produced from non-food feedstocks. Sunflower oil comprises only 1% of the total biodiesel feedstock. Other feedstocks include sunflower oil, pine oil and wood, fatty acids, tall oil and cottonseed oil. Imported soybean oil methyl ester (SME) and palm oil methyl ester (PME) have also contributed to the decreasing share of rapeseed oil in biodiesel production. The use of soybean and palm oil in conventional biodiesel is limited by the EU biodiesel standard, however, it is possible to meet the standard by using a feedstock mix of rapeseed oil soybean oil and palm oil (EC, 2019).

In the EU about 5 million ha of land is needed for the production of biofuel feedstocks including land located in third countries with a share of 25%. The total amount of cropland used for biofuel feedstock production is approximately 3%. In the EU ethanol production uses today around 2 million hectares of arable land within and outside the EU. Biodiesel production utilises 3 million hectares of land including imports as well. If co-products are taken into account, the net land use for feedstock production declines from 5 million hectares of gross land use to 2.8 million hectares net land use. Animal feed co-production in biofuel plants reduces animal feed deficit of the EU and in addititon saves the equivalent of 2.2 million ha of crop production within and outside the EU (EBB, 2016).

First-generation biofuels have been heavily criticised for their negative impacts on the environment, food security, and land use. The challenge is to support advanced biofuel development which is ecologically sustainable and commercially feasible (ABIDEEN et al., 2012). Several countries and regions have introduced policies or adopted standards to promote sustainable biofuels production and use but first of all the EU, the USA and Brazil. EU' renewable energy targets are similar in principle to renewable portfolio standards in the USA, where most states have binding or non-binding standards. The EU has the most comprehensive mandatory sustainability standard in place introduced in 2010. The U.S. Renewable Fuel Standard (RFS) requires specific levels of lifecycle greenhouse gas reductions compared to equivalent fossil fuel consumption. The U.S. standard currently address only greenhouse gas emissions, but California plans to address sustainability issues associated with liquid biofuels in the future.

Literature review

The *concept of sustainability* is derived from "sustainable development," defined by the Brundtland Commission as "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (BASIAGO, 1995). There have been several attempts to measure sustainability at different levels, i.e., within international and national policy, production systems, or products GNANSOUNOU, 2011). While the science of sustainability is evolving, its definition often depends on local conditions and stakeholders. Sustainability is not a fixed target leading to continued adjustment in response to changing conditions, knowledge, and priorities (DALE et al., 2013).

Sustainable development and sustainability science is related to economic development, social development, and environmental/resource sustainability (MENSAH, 2019). Sustainability does not only focus on the environmental impact, but on the three dimensions, namely "environment", "economy" and "social well-being", for which society needs to find a balance or even an optimum (FINKBEINER et al., 2010). Environmental sustainability refers to a condition of balance and resilience of societies, in which the global population can satisfy the consumption of natural resources needed, while ensuring that ecosystems can fulfil their function (AHERN, 2011). Environmental sustainability is linked to the concept of ecosystem services (BENNETT et al., 2015). Economic sustainability is the ability to maintain productivity and generate income (CONWAY – BARBIER 2013).

The expansion of biofuel production can lead to negative environmental impacts but several difficulties arise for an international agreement. For example, different feedstocks are produced in specific regions with certain soil or water conditions while inclusion of social criteria (e.g., labor conditions, food availability) is even more complicated (WU et al., 2012). LUZADIS et al. (2008) developed a novel systems approach to assess *bioenergy sustainability* incorporating the latest scientific knowledge and social values. GROOM, et al. (2008) made 12 policy recommendations to support biofuels certification standards including three general principles: promote sustainable and low-impact feedstocks with a small ecological footprint, maintain native and essential food crop habitats, and require net carbon neutral biofuels.

The global expansion of biofuels has triggered global debates on their environmental and social sustainability including their impact on the food production, land use change, biodiversity, energy efficiency and climate change (LEWANDOWSKI – FAAIJ, 2005; OLÁH et al., 2017; OLÁH et al., 2020; POPP et al., 2016; POPP et al., 2017).

The integration of environmental, economic and social issues in biofuels production have been discussed in a lot of studies (RAJAGOPAL – ZILBERMAN, 2007; MIZIK – GYARMATI, 2021; MIZIK, 2021). Holistic perspectives are needed due to the complexity of environmental and socio-economic problems in order to take advantage of potential synergy effect. The implementation of certification systems is the best instrument for the development of sustainable bioenergy systems (LADANAI – VINTERBÄCK, 2009). Sustainability evaluation of biofuels is a multicriterial problem (LORA et al., 2011). Biofuels sustainability is characterised by trade-offs between social, economic and environmental dimensions (MANGOYANA et al., 2013).

Multifunctionality indicates that agriculture can produce various non-commodity outputs in addition to food. Multiple commodity and non-commodity outputs (externalities or public goods) are jointly produced by multifunctional agriculture, although markets for most of the non-commodity outputs are still missing (COTES TORRES et al., 2007). Agriculture increasingly offers non-food-producing services and the EU plays a leading role in supporting the multifunctional characteristics of agriculture in the framework of the Common Agricultural Policy (CAP). The term of multifunctionality was formally defined by the European Commissionincluding three different functions of agriculture, namely the production, environmental and socio-economic function function (IGNACIUK, 2006). Current and future demand for food, feed, fiber, and energy require multifunctional landscapes to integrate ecosystem functions into a sustainable land use (SSEGANE et al., 2005). The criteria of multifunctionality are also valid for multifunctional liquid biofuels because multifunctional biomass production can reduce the pressure on productive land (IGNACIUK, 2006).

For a long time approaches to *sustainable biofuels* have focused on single issues, for example, producing feedstock on marginally productive lands instead of highly productive croplands to reduce competition with food production (CAMPBELL et al., 2008). In addititon, marginal lands require significant inputs of nutrients and water to maintain productivity (GOPALAKRISHNAN et al., 2009). Due to increased biomass feedstock production the optimization of all resources is essential to minimize conflicts in resource requirements (GOPALAKRISHNAN et al., 2009). Participation of stakeholders along the value chain is a crucial factor for sustainability of a bioenergy system (BUCHHOLZ et al., 2007). Both environmental and economic objectives can be pursued with full consideration of economic and environmental tradeoffs (SRIVASTAVA, 2007). Development of next generation biofuels may ease the competition between food, feed and fuel crops, but large-scale cultivation may have an impact on other resources and land use (KAZAMIA – SMITH, 2014).

A key aspect of *environmental sustainability* is the ability of biofuels to mitigate greenhouse gas (GHG) emissions (BRITZ – HERTEL, 2011). The life-cycle net greenhouse gas emissions from biofuels are an important consideration. Compared to the greenhouse gas emissions from conventional fuels, emissions from maize-based ethanol, biodiesel, and sugarcane or cellulosic ethanol are lower by 10–20%, 40–50%, and 85–95%, respectively (DE OLIVEIRA et al., 2005). Biofuel feedstocks should be grown with environmentally safe agricultural practices. The sustainability of any biofuel feedstock depends on sound environmental practices throughout the fuel-production life cycle. Furthermore, the ecological footprint of a biofuel should be minimized and so the land area needed to grow sufficient quantities of the feedstock (GROOM et al., 2008). Most environmental sustainability indicators for biofuels can be placed into six broad categories related to soil quality, water quality and quantity, air quality, climate forcing, biodiversity, and vegetation productivity (MCBRIDE et al., 2011).

Some studies have also explored the impact of biofuel production on biodiversity. Environmental impacts of bioethanol production can be controlled or mitigated by promoting technological change and development of new knowledge (OLÁH et al., 2020). HELLMANN – VERBURG (2010) show that direct effects of the RED biofuel target on land use are minor while indirect effects can cause up to 8% of additional land use change in the EU compared to a situation without biofuel targets. EGGERS et al. (2009) demonstrate that more species might suffer habitat loss with increasing biofuel production, however, habitat loss due to increasing biofuel cultivation in the EU is much smaller than habitat loss due to overall – demographic, economic, political and technological – developments. Renewable energy including also biofuels is a mitigation option for addressing climate change by offering prospects for meeting emission reduction commitments for rich countries and reducing energy import bills for low- and middle-income countries (HARANGI-RÁKOS et al., 2017; HARANGI-RÁKOS et al., 20218; HARSÁNYI et al., 2021).

Economic aspects of bioenergy sustainability involve short and long-term profitability of feedstocks, costs of production, transport and distribution of various fuels. From an economic perspective, the cost-effectiveness of some biofuel support policies is questioned (OECD, 2009). Economic factors are influenced by government subsidies, energy and feedstock prices, demand for diverse energy uses, and environmental consequences (DALE et al., 2013). In addition, investment costs and returns, prices of biofuels and other agricultural commodities and employment are also of great importance (MANGOYANA et al., 2013). Interest in liquid biofuels production and use has increased worldwide due to the growing scarcity of petroleum use and adverse global climate change (SOLOMON, 2008).

Social aspects of sustainable bioenergy involve preserving livelihoods and ensuring access to food and energy supply, and the safety of people, facilities, and regions. They also include obligations to respect human rights and long-term sustainability plans with periodic monitoring (DALE et al., 2013). The literature on social sustainability of biofuels has focussed on fighting poverty in the less developed regions of the world through biofuel enterprises including employment and income generation, local ownership, local access to energy and impacts on food production (MANGOYANA et al., 2013). From a social point of view, the impact of biofuel expansion on food prices and its effects on food security during the global financial crisis of 2007/2008 has been particularly controversial. A number of studies have examined the impact of biofuel production on food prices, producing estimates ranging from as little as 3% to as much as 75% for basic commodities (FAO, 2013). Other indicators of human well-being such as social capital development, trust, cultural values in relation to the implementation of biofuels are still limited in biofuels literature (MANGOYANA et al., 2013).

Due to widespread availability of biomass resources biomass-based fuel technology potentially employ more people than fossil-fuel based technology (KARTHA – LARSON, 2000). Existing biofuels industries have had a positive impact on rural economies and small farmers in several countries (RAJAGOPAL – ZILBERMAN, 2007). The biofuel sector is more labour-intensive in absolute terms and per unit of capital investment than the crude oil sector. Certification systems could help to guarantee benefits to small scale biofuel producers (VAN DAM et al., 2008). In addition, liquid biofuels offer development opportunities for small- and medium-sized electric grids at the community and village level. NEUWAHL et al. (2008) found generally positive, net employment effects in the agricultural, food, and industrial sectors. According to SOLOMON (2008) local economic effects could be relatively significant and positive in many rural agricultural areas. Policy makers have highlighted employment in supporting bioenergy research, development, and use (DALE et al., 2013). Integrated community development contributes to push up socio-economic development of the country (DEMIRBAS, 2008). Also, SMEETS et al. (2008) found that wages were higher for sugarcane harvesting and ethanol refining than for comparable employment in other sectors. For local economies, the driving force for biofuels production is often job creation and economic growth, while environmental protection and energy security may be considered bonuses (DALE et al., 2013). Indirect employment refers to jobs that result from upstream and downstream suppliers of material and technology (WEI et al., 2010) and higher purchasing power (DALE et al., 2013). Household income of those employed in the bioenergy industry is an indicator of well-being (DALE et al., 2013).

The food based biofuel production has generated concern about food security. Biofuel production is responsible for a much smaller effect on food prices than initially expected; and biofuel production has a smaller effect on cropexports from the US than previously estimated (OLADOSU et al., 2011). Furthermore, food price increases have lagged behind other traded commodity prices, all of which track the global price of oil. Most of the social indicators are not integrated into biophysical and economic processes to holistically understand sustainability of systems, therefore, social indicators that could be integrated into environmental and economic processes should be developed (MANGOYANA et al., 2013).

International collaboration on sustainable biofuels

In 2011, the Roundtable on Sustainable Biofuels (RSB) launched the RSB Certification System. Sustainability criteria and biomass and biofuels certification have been developed in increasing numbers in recent years as voluntary or mandatory systems but such criteria do not apply to conventional fossil fuels. If sustainability criteria are not developed globally for mutual recognition they could potentially become a major barrier for international bioenergy trade instead of promoting the use of sustainable biofuels production (VAN DAM et al., 2010). So far no negotiations for bilateral agreements on biofuels certification have been started even though this option was mentioned in the RED (EU, 2015).

The Energy Independence and Security Act (EISA) in the US established four quantitative annual mandates up to 2022: the total and advanced mandates that require fuels to achieve respectively at least a 20%, 50% and 60% GHG reduction as well as the biodiesel and the cellulosic mandates that are nested within the advanced mandate. 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 derived as the residual from the total RFS and the advanced biofuel mandates frequently referred to as the “non-advanced” or the “conventional” mandate and has been met with ethanol produced mainly from maize (EPA, 2013). The RFS caps maize ethanol volumes at 15 billion gallons (around 130-140 million tonnes of maize use as feedstock accounting for about 35% of total US maize production a year).

In 2009, Brazil also adopted new sustainability policies for sugarcane ethanol, including zoning regulation of sugarcane expansion. Brazil is the only emerging country that has initiated the Sugarcane Agroecological Zoning Plan (ZAE Cana) in order to stop deforestation and indirect land use change. Careful mapping and planning of land use are needed in order to identify which areas (if any) can be potentially used for sugarcane production (UNICA, 2010). Sugarcane expansion is limited to existing pasturelands that could be replaced with the crop according to the ZAE Cana. The programme constrains the areas in which sugar cane production can be expanded by increasing cattle density, without the need to convert new land to pasture. The programme is enforced by limiting access to development funds for sugar cane growers and sugar mill/ethanol plant owners that do not comply with the regulations.

Bonsucro was established in 2008 to promote sustainable sugarcane production, processing and trade worldwide. Bonsucro aims to reduce the environmental and social impacts of sugarcane production while recognising the need for economic viability by setting sustainability standards and certifying sugarcane products including ethanol, sugar and molasses. About 25% of global sugarcane land is engaged In Bonsucro. Bonsucro developed measures for greenhouse gas emissions and the standard can be used to demonstrate compliance with the EU Renewables Directive. The Bonsucro certification system includes two certification options, namely "Bonsucro" (compliant with Bonsucro requirements) and "Bonsucro EU" (additional requirements that are needed for EU RED compliance in line with the RED 28/2009/EC, FQD) 30/2009/EC and amendments laid down in Directive 2015/1513. Bonsucro has developed two standards, the "Bonsucro Production Standard" including criteria for achieving sustainable production of sugarcane and all sugarcane derived products in respect of economic, social and environmental dimensions and the "Bonsucro Mass Balance Chain of Custody Standard" enabling the sustainable supply of a product including all stages from the feedstock production up to consumption (BONSUCRO, 2014).

The EU policy for renewable energy is established in the EU Energy and Climate Change Package (CCP) adopted in 2009. 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, and a 10% minimum target for renewable energy consumed by the transport sector in all Member States. The Renewable Energy Directive (RED), which is part of this package, states that renewable fuels (including non-liquids) should increase to 10% of total transport fuel use by 2020 on an energy equivalent basis, since this is where GHG emissions are increasing the fastest. EU renewable energy targets are similar in principle to renewable portfolio standards in the USA, where most states have binding or non-binding standards. In the RED specific sustainability requirements are also defined for conventional liquid biofuels. Biofuels may not be made from raw materials produced on land with high biodiversity value (primary forest and other wooded land, biodiverse grasslands and areas designated for nature protection purposes) and on land with high carbon stock (wetlands, peatlands and continuously forested areas. In addition, the Fuel Quality Directive (FQD), requires fuel producers to reduce the GHG intensity of transport fuels by 6 % by 2020. FQD together with the RED also regulates the sustainability of biofuels (EC, 2009a; EC 2009b).

Both directives (RED, FQD) were amended in 2015 by the "Indirect Land Use Changes" (ILUC) Directive by introducing a 7% cap on renewable energy in the transport sector coming from food and feed crops and setting non-binding national targets for advanced biofuels (non-food based) at 0.5% for overall energy use (SCARLAT et al., 2015). Italy was the first EU Member State to mandate the use of advanced biofuels (0,1% in 2018, 0.2% in 2019, and 1% in 2020). Since a high share of double-counting biofuels results in a relatively limited share of food-based biofuels, implementing a 7% cap in these countries has not affected a further significant growth of food-based biofuels so far. Only biofuels that meet the sustainability criteria for biofuels and bioliquids as laid down in the RED may count towards the 10% target. Under current market conditions it is unlikely that the 7% cap will be reached in the EU by 2020. According to the Directive regulating the ILUC of biofuels consumed in the EU must comply with strict sustainability criteria based on the minimum level of greenhouse gas (GHG) savings, appropriate land use, and monitoring requirements for any potentially adverse effects. Sustainable biofuels must achieve GHG savings of at least 50% in comparison to fossil fuels. From 1 January 2018, this number rose to 60% for biofuels produced in installations starting operation after 5 October 2015 and 50% percent for all other plants including emissions from cultivation, processing, and transport (EC, 2019).

RED II set a new overall renewable energy target of 32% and a 14% renewable energy target for the transport sector by 2030. The volume of renewable energy for the transport can be cut by the proposed multipliers for reaching the overall mandate of 14% renewable energy in transport; electric transport (4x for road and 1.5x for rail transport), the use of biofuels by the aviation and maritime sector (1.2x) and double counting advanced biofuels produced from agricultural and forestry by-products and waste fats and oils. The EU capped the RED II share of conventional based biofuels to 1% above consumption levels by Member States in the year 2020, up to the overall cap of 7% for each Member State. The RED II also sets binding targets for the use of advanced (non-food based) biofuels to 3.5% by 2030. The double counting factor contributed to the expansion of biofuels produced from waste fats and oils. The RED II established ambitious goals for biofuels produced from cellulosic feedstocks, but so far the market introduction of these advanced biofuels have been limited (1%). Sustainability criteria of the RED II restricts the use of biofuels produced from palm oil in high-risk ILUC areas (areas that have undergone recent deforestation or conversion of grasslands to croplands) at the 2019 levels until 2023, and will reduce them to zero by 2030. The use of palm oil as low ILUC risk biodiesel feedstock requires certification. This will have an impact on palm oil demand and potentially some soybean products. The import of ILUC palm oil in the EU is possible but it does not count towards meeting RED II's targets. The increasing share of electric cars may reduce total fuel demand, thereby biofuel consumption as well (EC, 2019; OECD/FAO 2019).

Member States of the EU must oblige fuel suppliers to reduce the life cycle GHG emissions per unit of energy of their supplied fuels by up to 10% (mandatory 6%) compared with the fuel baseline of 2010. The objective of the EU is to reduce GHG emissions from transport by 60% by 2050 compared to 1990 levels. While the EU's GHG emissions have been declining since 1990, GHG emissions from transport have increased. Without further policy action, the EU's transport GHG emissions will be 15% above 1990 levels by 2050. In 2014 GHG emissions from transport were 13% higher than in 1990 (van Grinsven and Kampman, 2015). Some Member States have fully transposed the ILUC Directive and set the sub-target for advanced biofuels at 0.5%, others set a sub-target lower or higher than 0.5% by 2020. Hungary, Sweden and the UK have not introduced sub-targets. 20 Member States decided to establish the double counting mechanism for biofuels. The FQD has been implemented in all Member States of the EU. Fuel suppliers that fail to meet their obligation are liable to a penalty or can pay a buy-out price but in Latvia and Denmark no penalty system is in place (ePure, 2018).

In theory, if the average GHG intensity of biofuels decreases as result of the ILUC Directive, the FQD target could also be met more easily. The actual shares in biofuel volume may be lower in practice than the 10% RED target in 2020 because of the administrative contribution of biofuels due to the higher multiplication factor for renewable electricity in rail and road transport and the increasing use of double-counting biofuels. This may effectively reduce the contribution of the RED policy measures towards meeting the FQD target (where double-counting does not apply). Biofuels cannot be double counted under the FQD; this is the primary reason why the two targets are not completely aligned. There is a difference between implementation of the ILUC Directive, the RED and the FQD: the RED obliges Member States to take responsibility directly for meeting targets, while the FQD requires Member States to oblige fuel suppliers to meet the FQD target. This means that a Member State implementing the FQD can not be held accountable if targets are nevertheless missed (VAN GRINSVEN - KAMPMAN, 2015).

The EU bioenergy sustainability framework has been reinforced under the recast Renewable Energy Directive setting national limits, which will decrease to zero by 2030, for high-ILUC biofuels, bioliquids and biomass fuels produced from food or feed crops for which a significant expansion of the production area into land with high carbon stock is observed. These limits will affect the amount of these fuels that can be counted when calculating the overall share of renewables and the share of renewables in transport, however, it is possible to exempt from the national caps those biofuels, bioliquids and biomass fuels that are certified as low ILUC-risk. Furthermore, in 2019 the Commission adopted a Delegated Act on high and low-ILUC risk biofuels to promote advanced biofuels and other low carbon fuels (renewable electricity, liquid and gaseous transport fuels of non-biological origin. Advanced biofuels have a very small market share today in the EU (1%) but there is a significant potential to scale-up production. Scientific assessment is needed to justify an enlargement of the feedstock base for advanced biofuels laid down in REDII (EC, 2019).

As all agricultural production is regulated with respect to environmental impacts no more impacts should be expected from biofuel crop production than other crop production. Since the RED was passed, more agricultural land has been removed from productive use than would be needed to supply all biofuel plants of the EU. No agricultural land in the EU has been removed from food production for first generation biofuels and land use effect is lower when co-products are sent to the animal feed market due to t e decrease in net land use (LANGEVELD et al., 2014). The cultivation of biofuel feedstocks can potentially result in negative environmental impacts, which are site-specific and depend on the agricultural practices applied, however, neither site-specific data nor data related specifically to the local environmental impacts of cultivation of feedstocks for biofuel production are available. Cultivation of feedstock used in biofuel production compared to total agricultural activities is limited, therefore that associated environmental impacts are insignificant (EC, 2019).

Some of the Member States in the EU have developed national voluntary systems, while others rely on voluntary schemes adopted by the European Comission. The sustainability criteria have been successful in minimizing the risk of direct environmental impacts associated to biofuels regardless whether they are produced domestically, or imported from third countries. Voluntary schemes have become the main tool to demonstrate compliance with the EU biofuel sustainability criteria. Furthermore, RED II includes a reinforced sustainability. Today 14 voluntary schemes have been recognised for demonstrating compliance with the sustainability and greenhouse gas saving criteria of RED I for biofuels and bioliquids (EC, 2019).

Summary

The EU is the global frontrunner on sustainability and has introduced regulations under the RED (Renewable Energy Directive) and Fuel Quality Directive (FQD) that lay down sustainability criteria that biofuels must meet before being eligible to contribute to the binding national targets that each Member State must achieve by 2020. In Europe, the revised EU Renewable Energy Directive for 2020-2030, approved in December 2018, sets a target for a 14% share of renewable energy in the transport sector by 2030, with a sub-target of at least 3.5% use of advanced biofuels and biomethane. The Directive also places a 7% cap on the share of the overall target that can be met by conventional biofuels based on feedstocks that also could be used as food, reflecting EU concerns about competition between food and fuel and about potential indirect land-use change impacts.

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