Overcoming hurdles for innovation in industrial biotechnology in Europe

Cellulosic Ethanol

Summary

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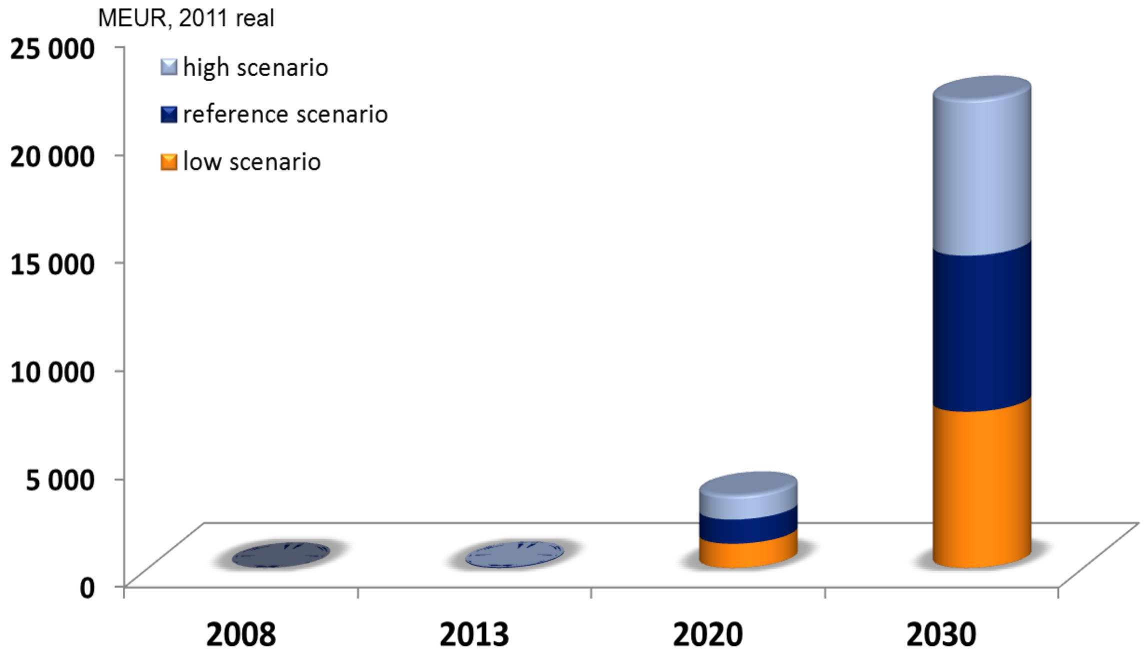
the European Union

The BIO-TIC project aims to identify hurdles and develop solutions to the large scale deployment of Industrial Biotechnology in Europe. Advanced biofuels are one of five product groups which we have identified as having significant potential for enhancing European economic competitiveness and introducing cross-cutting technology ideas.

This document is a summary of the findings related to cellulosic ethanol at the mid-way stage of the project. It has been produced as a discussion piece in order to collect stakeholder's thoughts on the hurdles within this sector and ideas for how these hurdles can be overcome to capture the full potential of cellulosic ethanol in Europe.

There are currently over 70 bioethanol plants in operation in Europe, most of which utilize 1st generation (1G) feedstocks such as wheat, maize and sugar beet. Bioethanol can also be produced from other feedstocks such as agricultural and forestry residues, energy crops and the biological fraction of municipal solid waste (MSW) and this is known as cellulosic, advanced or second generation (2G) bioethanol. Globally, the production volumes of cellulosic ethanol are still very low, as the technology is being developed from demonstration to commercial scale. European ethanol demand is currently satisfied by first generation production because the leading cellulosic ethanol producers, i.e. USA and Brazil, are barely able to meet their own biofuel quotas.

In 2013, the EU ethanol demand for transport fuel was estimated at 3.8 BEUR which represents a growth in volume of around 12% per annum between 2008 and 2013. In light of current plans for ethanol facilities, and assuming the current expectations regarding ethanol trends remain verified (cf. annex), the market value of cellulosic bioethanol is expected to reach 14.4 BEUR in 2030.



The vision for cellulosic bioethanol in the EU

Ambitious greenhouse gas emission reduction targets for 2030 will continue to drive the consumption of renewable fuels, with or without the presence of separate biofuel quotas. The use of biofuel feedstocks that (could) compete with the food or feed chain will no longer be politically supported. The demand for cellulosic ethanol is therefore expected to increase rapidly through to 2030. As fuel ethanol is unlikely to become cost-competitive compared to fossil-based fuels without political support by 2030, cellulosic ethanol will need to replace existing 1G ethanol consumption. This would mean retrofitting 1G ethanol production to using cellulosic feedstocks.

Today's biofuels market is largely determined by policies and regulations related to fuel blending. Because it is subject to the biofuel obligation, the blending company is the one holding the decision-making power over whether to use 1G or cellulosic ethanol. While the biofuel obligation in transport has been set to 10% for 2020, recent developments within the EU institutions indicate an aspiration to limit the share of 1G biofuels within this target to 7%. The desire to drive biofuel production away from the food and feed-based feedstocks and value chains will certainly contribute to the uptake of cellulosic ethanol. However, the by far greatest driver for cellulosic biofuels is the "double counting principle" included in the Renewable Energy Directive, according to which a 5% biofuel share suffices to fulfill the requirements for the 10% obligation provided it is produced from cellulosic feedstock. Other opportunities for increasing the market uptake of cellulosic ethanol lie in rising fossil oil prices and, where appropriate, the potential valorization of additional products from bioethanol production and the co-processing of biofuels with fossil fuels to lower investment and environmental costs.

The uptake of advanced biofuels is highly policy-driven and an increasing demand is expected in the future due to blending quotas in the Fuel Quality Directive (FQD) and the proposed Renewable Energy Directive RED amendment. However, it remains unclear whether the European market will truly benefit from these measures because there is little governmental support for financing demonstration and scale-up, and the political climate does not give investment certainty. When combined with investment costs of 150-250 million per plant and with a long exit time, there is a real difficulty in finding venture capitalist funding. Bioethanol production is cheaper in Asia and South America than Europe; as a result, this can impact investments in research and innovation as well as in European production facilities. As a result, advanced ethanol may be produced elsewhere in the world and imported and used in the EU to fulfill blending mandates.

There are several routes to producing cellulosic ethanol, which are at various stages of development world-wide. These generally fall into biochemical routes, thermochemical routes and hybrid thermochemical-biochemical routes and differ, for example in their development status, what feedstocks can be used, as well as whether co-products can be produced or not.

Biochemical routes to producing cellulosic ethanol

The biochemical route is the most developed route for producing ethanol from lignocellulosic biomass globally. Lignocellulosic biomass is pre-treated (chemically, thermally, biologically or a combination of these) to increase the surface area of the biomass and facilitate the access of enzymes which break down the sugar-containing cellulose and hemicellulose fractions to C5 and C6-sugars. The subsequent biochemical conversion of the C6-sugar fractions into ethanol is typically carried out using yeasts similar to those in the potable alcohol industry. It is also possible to use bacteria for fermentation but this route requires a sterile environment. One of the downsides to bioethanol production processes using yeast-based systems is the loss of a part of the available sugars in the form of CO_2. In order to avoid this, it is possible to ferment the sugars by homo-acetic bacteria and the produced acetic acid can then be chemically converted into ethanol.

Fermentation of the C5-sugar fraction to ethanol either requires GM yeast strains or other microorganisms which are able to process C5-sugars. However, co-fermentation of both C5 and C6 sugars is normally a slow process which potentially limits the yield in a specific timeframe.

Ethanol production using biochemical conversion processes have the potential to be integrated into a biorefinery, thus reducing the costs of cellulosic ethanol production, however alternative applications for lignin need to be developed. Most commonly, the lignin is burned and serves as a heat and energy source for maintaining the process. Routes to using lignin, for example, as a source of phenols in duroplastic and thermoplastic applications, are currently being explored.

Hybrid-thermochemical routes to producing cellulosic ethanol

An alternative for producing bioethanol from lignocellulosic feedstock is to gasify the biomass to produce syngas which is then subsequently either fermented using bacteria into bioethanol (IB route) or converted to ethanol and other alcohols using chemical catalysts (non-IB route). There are two principal advantages of gasification based routes for ethanol production 1) all of the organic matter within the feedstock is broken down, which results in the release of a higher proportion of carbon for ethanol production and 2) gasification is suitable for all biomass sources, for example highly heterogeneous feedstocks such as municipal solid waste[1]. The disadvantage of this route is however that all of the biomass is converted, thus, there is little scope for valorization of co-products (and hence deriving additional value streams) unlike for the biochemical conversion routes described above.

Large-scale cellulosic ethanol production is largely hampered by feedstock-related hurdles. Since advanced biofuels are by definition produced from non-food biomass, new, high volume but sustainable feedstocks need to be exploited. In this regard, agricultural residues, forestry residues and the biological fraction of municipal solid waste show significant potential. However, it is necessary to address potential indirect effects associated with using some feedstock streams currently considered 'wastes' and 'residues' and advance best practices to develop or improve their sustainable mobilisation.

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[1] The moisture content of the biomass needs to be within specific limits for gasification. The moisture tolerance limits for gasifiers vary.

The table below summarizes the hurdles and some solutions that can be envisaged to overcome the bottlenecks related to cellulosic ethanol. The hurdles that are highlighted in green apply to cellulosic ethanol specifically, but are also an issue for IB in general. The white cells apply only to cellulosic ethanol. The cells that have been left blank indicate that no solution has yet been formulated with regards to that barrier.

Stakeholder engagement is crucial in ensuring that actions are developed which best fit the needs of this sector. The BIO-TIC project would greatly welcome any comments you might have on this document, hoping that your valuable input will contribute to setting the groundwork for a targeted workshop dedicated to advanced biofuels which will take place on 23rd October in London, UK.

We are particularly interested in your views on the market projections to 2030, whether we have missed any key hurdles and on any solutions which you could envisage to overcome these hurdles. Please send any comments to bio-tic@europabio.org

Short term hurdles	Solution proposed	
	R&D	Non technological
Efficient use of side streams	*-Process optimization and/or provision of novel (and newly applied) technology to provide more efficient downstream and recovery processes to meet quality and regulatory requirements*	
IPR problems in business-oriented projects		*-Competitors should not be involved in the same projects, one on one partnerships are more efficient*
Insufficient infrastructure for collection of agricultural residues		*-Use rural development funds to support access to machinery and infrastructure* *-Development of Public Private Partnerships to upscale biorefineries* *-Implement better conditions for loans* *-Development of infrastructure for the logistics of the supply chains* *-By-products and waste from (second generation) ethanol production can be used for the production of secondary and potentially high value added products. This would solve part of the logistics problem (feedstock and use of waste).*
Underdeveloped markets		*-Encourage companies to uptake biobased products to secure the end market. This will also encourage investment and market uptake.* *-Development of infrastructures to support the technology and the products e.g. cars, engines* *-Optimization of broad spectrum product to yield highest value* *-R&D focus should be on the properties of a product rather than on the replacement of chemical fossil-based formulations*
Cost and efficiency of enzymes	*-Develop synthetic systems to produce enzymes* *-Identify and develop novel and more robust*	

	enzymes *-Research organisations should cover industrially relevant production of enzymes*	
High Downstream Processing cost (from ½ to 2/3 of total production costs)	*-Development of membrane technologies* *-Optimisation of biorefineries, e.g. by-products from biorefineries can be used for animal feeds* *-Create plants capable to use multiple feedstocks to make multiple products*	
Lack of continuous production capacity		
Fluctuating feedstock prices and security of feedstock supply		*-International cooperation*
Public perception and acceptance of GMOs		*-Develop a communications strategy addressing:* *1/Mobilization of intermediary associations (e.g. NGOs, umbrella organisations) to promote biobased products based on scientific fact finding.* *2/Involvement of all stakeholders (including the media & consumers) in innovation projects from the beginning*
Insecurity of price development		
Little governmental support for financing demo and large-scale facilities in Europe		*-Development of funding programmes for bioethanol* *-Public-private initiatives and co-funding to provide seed capital to overcome financial risks, and enhancement of cooperation between the public and private sector e.g. through PPPs* *-Implementation of more incentives in favour of the feedstock supply chain (e.g. Renewable Transport Fuel Certificates; incentives for farmers and the forestry industry to collect material; incentives to support biomass production on non-agricultural land e.g. willow)*

Medium term hurdles	Solution proposed	
	R&D	Non technological
Political situation insecure for investments, especially for other than food and feed feedstocks		*-Political support for second generation biofuels* *-In the long term, a unified tax system for the EU is required* *-Blending should be harmonized by setting e.g. a minimum limit* *-Public financing* *-Investment support* *-Stable financial and regulatory support from governments for cellulosic ethanol fuels* *-Efficient instruments to address investment risks for emerging technologies entering the market along with the implementation of financing instruments and tools which combine options in order to build the foundations of sustainable investment in Europe's biobased infrastructure as well as the long-term stable growth of this industry*
Lack of public acceptance for biofuels		*-Organization of communication and dissemination activities to the public at large on the benefits biofuels and disadvantages of fossil fuels to raise awareness and to change the opinion and the cultural behavior.* *-Labeling of fuel pumps (5% blended with bio-ethanol)* *-Implementation of educational programmes, and specific educational activities targeted at the secondary school level.*
Low biofuel blends (5%) / 5% bioethanol/biodiesel		*-Mandatory biocomponent blend in transport fuels*
Securing outlets		

Long term hurdles	Solution proposed	
	R&D	Non technological
Definition of waste and waste handling		

ANNEX

The market projection is based on the following assumptions

- The EU will reach its biofuel target of 10% in 2020.
- The total fuel consumption in road transport is expected to decrease 9% from 2013 to 2030[2].
- The share of ethanol of all cellulosic biofuels is assumed to remain constant 30%.
- By 2030 the increasing use of electric cars will not have substituted ethanol demand on the market (even though the effect on bioethanol consumption will be larger than on diesel fuels).
- Stringent emission standards will favour the use of gasoline to diesel engines.

Moreover, the reference, high and low market scenarios assume a separate cellulosic biofuel mandate of 2%, 3% and 1% of all road transport fuels by 2020, respectively.

[2] European Commission (2013), *"EU energy, transport and GHG emissions – Trends to 2050"*