SOLVENTS

Acetic acid (AA)

AA is used as raw material in industrial chemicals and solvents as well as the food, pharmaceutical, textile and cosmetic industry. It can be attained through various pathways: fermentation of sugars (from pathways A, B or E), carbonylation of methanol generated from syngas (pathway I) and extraction from spent liquor from sulphite pulping of woody biomass (pathway D).

PERFORMANCE

Sugar and starch crops are most typically used to make AA, however lignocellulosic biomass is a more sustainable alterative concerning competition with food. Bio-based acetic acid has benefits over conventional acetic acid, such as low toxicity, biodegradability and sustainability. It offers direct drop-in replacement for fossil-based acetic acid.

DRIVERS AND BARRIERS

Driver

- Drop-in can replace fossil-based AA with more sustainable alternative.

Barrier

- AA can be produced through ethanol and methanol, and renewable fuel mandates around the world favour the blending of biomethanol and ethanol in fuels instead of use for chemicals.

ROADMAP ACTIONS

Acetic acid can be produced by pathways (A/B/D/E/I). The roadmaps for these pathways include actions for stakeholders to take to scale up these pathways including the production of acetic acid.

MARKET OUTLOOK

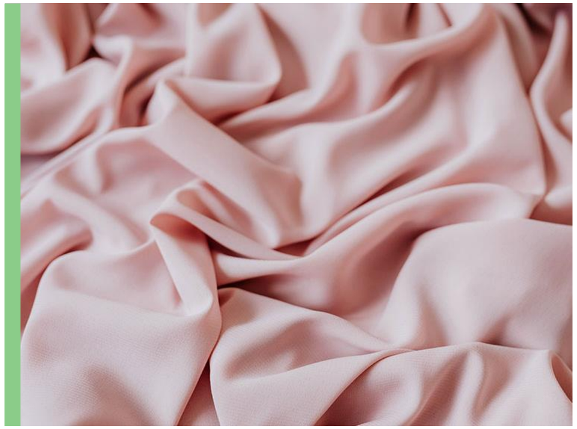
Introducing incentives to use biomethanol and ethanol not only in fuels but also in the chemical sector can become a major driver for the bio-based acetic acid market. It can grow at a CAGR of above 4% during 2019 to 2026 according to findings from Mordor Intelligence.

EU BIOREFINERY DEPLOYMENT

BUILDING BLOCK

Biomethanol

Biomethanol is identical with fossil derived methanol. It is used to produce various daily-life products (e.g. building materials, foams, resins, plastics, paints, polyester, pharmaceuticals). It is most typically produced via gasification of lignocellulosic biomass (pathway I) but can also be attained as a side product from pulping (pathway D).



PERFORMANCE

Biomethanol can be produced from a range of biomass feedstock including municipal solid waste, agricultural and forestry residues. Methanol has low environmental impact since it biodegrades quickly. Making and using biomethanol do not only reduce carbon dioxide emissions, it also reduces other harmful air pollutants including nitrogen and sulphur oxides (NOx and SOx), volatile organic compounds (VOCs), particulate matter and other toxic pollutants. It offers direct drop-in replacement for fossil-based methanol.

DRIVERS AND BARRIERS

Driver

- Drop-in can replace fossil-based methanol with more sustainable alternative.

Barrier

- Biomethanol production costs are higher than fossil-based.
- Renewable fuel mandates around the world favour the blending of biomethanol in fuels instead of use for chemicals

ROADMAP ACTIONS

Biomethanol can be produced by pathways A, B or E. The roadmaps for these pathways include actions for stakeholders to take to scale up these pathways including the production of 1,4 BDO.

MARKET OUTLOOK

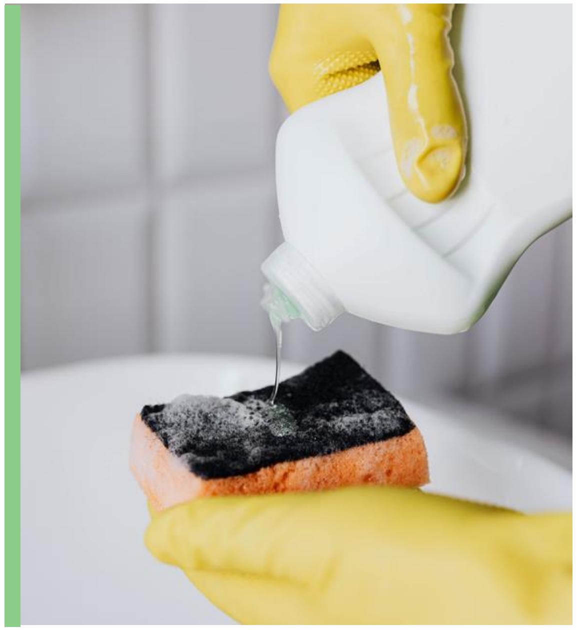
Incentives to use biomethanol in the chemical sector instead of the fuel market which is currently the case can become a clear driver for biomethanol demand. Biomethanol demand for chemicals can increase sharply from 0 to about 500 kta in a high growth scenario depending on the incentives being introduced.

EU BIOREFINERY DEPLOYMENT

LUBRICANTS

Fatty acid PEG esters (PEG)

PEGs and PEG derivatives are applied in the food industry, pharmaceutical and biomedical field. They are further used as surfactant and cleansing agent. They are produced from pathway C from oil crops, wastes and residues.



PERFORMANCE

PEG are produced from different plant oils. It is possible to derive them using waste/residue fats, oil and greases which do not have indirect land use effects. PEG are readily biodegradable and considered to be low hazard to water.

DRIVERS AND BARRIERS

Driver

- PEG could replace Nonylphenol Ethoxylates which are restricted in the EU due to their negative environmental effects.
- Applications in cosmetics, personal care, textiles and lubricant industry are the driving sectors.

Barrier

- High costs and difficulties to justify price premiums for bio-based alternatives.
- Difficult and costly to prove sustainability.

ROADMAP ACTIONS

Bio-based fatty acid PEG esters can be produced by pathway C. The roadmap for this pathway includes actions for stakeholders to take to scale up this pathway including the production of fatty acid PEG esters.

MARKET OUTLOOK

One driver for PEG is the need to substitute nonylphenol ethoxylates. The global Fatty Acid Ester Market has a predicted CAGR of 4.5%. There are no specific estimations for PEG available.

EU BIOREFINERY DEPLOYMENT

SURFACTANTS

Fatty alcohol ethoxylate (FAE)

FAE is mostly utilized in detergents, personal care products as well as textile and leather processing. Furthermore, they are applied in fibre finish, crop protection, water treatment, paints and coatings and lubricants. FAE is produced from fatty alcohols produced in pathway C from oil crops, waste and residues.

PERFORMANCE

FAE are derived from fatty alcohols produced from vegetable oils and ethylene oxide, which is typically derived from fossil-based resources, which leads to FAE which has a bio-based share of about 60%. However, ethylene oxide can also produced from sugar or starch crops (pathway A and B) which leads to 100% bio-based FAE. FAE exhibit a low potential to bioaccumulate in aquatic organisms. They are non-ionic and biodegradable. The production and use of FAE generates lower GHG emission compared to surfactants derived 100% from fossil resources. It is possible to produce partially bio-based fatty alcohol ethoxylates cost competitively using fatty alcohols derived from vegetable oils. The global ethoxylates market is expected to grow to reach USD 17.9 billion by 2027 with an estimated CAGR of 4% from 2020-2027. According to JRC the European market accounts for 34,7 % of the global market. The average price is estimated to be 1,77 EUR and the EU-28 market for FAE estimated at 548 kt/a. The global market value for fatty alcohol ethoxylates is EUR 4,662 million.

DRIVERS AND BARRIERS

Driver

- Uncertainty of secured steady supply due to the limited number of large-scale producers.

Barrier

- Can replace nonylphenol ethoxylates which have a negative aquatic environment.

ROADMAP ACTIONS

Bio-based fatty alcohol ethoxylates can be produced by pathway C and either of A, B or E. The roadmaps for these pathways include actions for stakeholders to take to scale up these pathways including the production of fatty alcohol ethoxylates.

MARKET OUTLOOK

The need to remove nonylphenol ethoxylates from the market creates a clear driver. CAGR are estimated with 4%.

EU BIOREFINERY DEPLOYMENT

BUILDING BLOCKS

Lactic Acid (LC)

LA is used as monomer in the production of PLA. It is further applied in cosmetics, pharmaceuticals and food products. LA can be converted to different other chemicals. It is produced from fermentation of sugars derived from sugar crops, oil crops or lignocellulosic biomass (pathways A, B and E respectively).

PERFORMANCE

PLA is one of the first renewable polymers able to compete with fossil-based polymers, combining unique functional properties like transparency, glossy appearance, durability. The production of LA and PLA offers significant reduction in GHG emissions and non-renewable energy use. Compared to conventional fossil-based plastics, PLA offers additional end-of-life options of organic recyclability. Currently its production is not cost competitive with fossil-based counterparts.

DRIVERS AND BARRIERS

Driver

- Increased use in packaging, textiles, agriculture, cosmetics and pharmaceuticals

Barrier

- Production costs are higher than of fossil-based counterparts.

ROADMAP ACTIONS

Lactic acid (poly lactic acid) can be produced by pathways A, B or E. The roadmaps for these pathways include actions for stakeholders to take to scale up these pathways including the production of lactic acid or poly lactic acid.

MARKET OUTLOOK

Increased use of bio-based polylactic acid (PLA) or PLA composites in packaging, textiles, agriculture, cosmetics and pharmaceuticals drive the lactic acid market. In 2019 Grand View Research predicted a market growth of 18.7%. However, a recent report estimates the global CAGR for LA between 2021-2026 with 2.5% taking the impact of the current pandemic into account.

EU BIOREFINERY DEPLOYMENT

RESINS

Lignin based phenolic resins (LPR)

LPR are used for resin impregnation, brake linings, electrical components, cookware, laminate, adhesives and molds. The commercial production route of LPR is using Kraft lignin as feedstock (attained from pathway D). Alternatively, lignin can be derived from pathway E from pre-treatment of lignocellulosic biomass and from pyrolysis oil produced in pathway J.

PERFORMANCE

Phenolic resins are thermosetting resins. They are strong, heat and impact resistant and have a high resistance to chemical corrosion and moisture penetration. There are three main motivations to substitute the phenol and formaldehyde, which are to move to more sustainable bio-based raw materials, to improve health and safety during manufacturing and use and to enhance performance of the resin (i.e. mechanical properties and higher thermal stability). They are seen to offer the same technical properties with the 100% fossil based phenolic resins while offering reduction in GHG emissions and energy use. They can be produced cost competitively.

DRIVERS AND BARRIERS

Driver

- Only partial substitution of phenol with lignin is currently technically feasible

Barrier

- lower reactivity and additional energy and costs required to modify the lignin to increase its reactivity constitute a barrier for its wider industrial application.

ROADMAP ACTIONS

Lignin based phenolic resin can be produced by pathways D, E or J. The roadmaps for these pathways include actions for stakeholders to take to scale up these pathways including the production of lignin based phenolic resin.

MARKET OUTLOOK

Technical barriers and the additional energy need to modify lignin hindering wider industrial application were LPR could substitute phenolic resins with lignin. The phenolic resins market is expected to grow by a CAGR of 5.5%. There are no specific CAGR for Lignin based phenolic resins available.

EU BIOREFINERY DEPLOYMENT

FIBRES

Micro fibrillated cellulose (MFC)

MFC finds applications across multiple sectors including pulp & paper, paint & coatings, adhesives, cement & concrete, cosmetics, oil & gas, homecare and agro-chemicals. It is produced under pathway D from pulping following a fibrillation process of cellulose fibres.

PERFORMANCE

MFC can be derived from non-food biomass feedstock. Normally wood pulp is used as feedstock, however it can be extracted from plant-waste and be also produced by bacteria. MFC is non-toxic and safe for food contact. MFC has the potential to substitute plastics and aluminium in packaging materials, which would reduce CO_2 emissions. Used in papermaking MFC can lead to a reduction of fibres used while keeping the same performance which is estimated to reduce cost by as high as USD 149 per tonne and a fibre reduction of up to 20%. With MFC it is possible to produce lighter packaging products that are durable and stronger.

DRIVERS AND BARRIERS

Driver

- Increased demand for environmental friendly materials; e.g. MFC is VOC-free and biodegradable
- Regulation on fossil-based products and hazardous chemicals is expected to increase MFC demand.

Barrier

- High costs of manufacturing and scale-up

ROADMAP ACTIONS

Microfibrillated cellulose (MFC) can be produced by pathway D. The roadmap for this pathway includes actions for stakeholders to take to scale up this pathway including the production of MFC.

MARKET OUTLOOK

A general driver for MFC is the demand for environmentally friendly products and regulation aiming to reduce the use of fossil-based and hazardous chemicals. The use in aviation and transport is also driving this market. The market is valued to grow with a 13.6% CAGR until 2026. The nanocellulose market, which is including MFC is expected to grow even with 21% until 2026 and it is assumed that this trend will continue until 2030.

EU BIOREFINERY DEPLOYMENT

POLYMERS

Thermoplastic starch (TPS)

TPS is a brittle material, but blended with other polymers, fillers or fibres the properties can be improved. It is an attractive material for sustainable packaging and films, especially for food packaging.
It is produced from starch attained from pathway B.

PERFORMANCE

Starch-based plastics can be used in a variety of applications since they can be incorporated with various fossil-based polymers or biopolymers to create unique composite materials. Its environmental impact is highly dependent on the materials the composite is made of. Therefore, LCA results for starch composites show significant variation. Additives in starch-based plastics can count for up to 40% of the emissions. Starch-based plastics are compostable and provide replacement of fossil-based plastics in various packaging applications.

DRIVERS AND BARRIERS

Driver

- Biodegradability, compostability and recyclability along with GHG saving when starch is sustainably sourced.

Barrier

- Lack of knowledge and communication of environmental benefits of TPS containing products.

ROADMAP ACTIONS

Thermoplastic starch can be produced by pathway B. The roadmap for this pathway includes actions for stakeholders to take to scale up this pathway including the production of thermoplastic starch.

MARKET OUTLOOK

A lack of knowledge about the environmental benefits of TPS is constraining the market growth. However, if awareness raising campaigns succeed applications which require the functionalities such as biodegradability and recyclability along with GHG savings provide market drivers. The CAGR is currently predicted above 7%.

EU BIOREFINERY DEPLOYMENT

BUILDING BLOCK

1,4-Butanediol (BDO)

BDO is an industrial chemical used as solvent and building block to produce plastics, elastic fibres and polyurethanes. BDO is biodegradable and mostly produced through fossil-based pathways. Bio-Based BDO is a drop-in product which could replace fossil BDO since it is chemically identical. It is produced from fermentation of sugars (attained from Pathways A, B or E).

PERFORMANCE

Bio-based BDO can be produced 100% bio-based. BDO is toxic and BDO derivatives come with health and safety issues. BDO is biodegradable and does not accumulate in nature. Fermentation of bio-based BDO is an energy intensive process. LCA conducted conclude on bio-based BDO that Green House Gas emissions can be reduced by 60% across the life cycle compared with fossil-based BDO. Bio-BDO is identical to fossil-based bio-BDO (i.e. has the same molecular structure). It offers direct drop-in replacement for fossil BDO. It is not currently not cost competitive with fossil-based BDO.

DRIVERS AND BARRIERS

Driver

- Increased use of biodegradable films (e.g. in agriculture)

Barrier

- Regulatory provisions (e.g. EU fertilizer regulation) are currently not sufficient.
- Potential to increased use of BDO in automobile industry not realised due to lack of standardization.

ROADMAP ACTIONS

Bio-based 1,4 BDO can be produced by pathways A, B or E. The roadmaps for these pathways include actions for stakeholders to take to scale up these pathways including the production of 1,4 BDO.

MARKET OUTLOOK

The production of bio-based and biodegradable plastics used e.g. used as agricultural mulch films can be a major driver for BDO, especially if supported by policy and regulation. There is a review of the EU fertilizer directive in 2024, which provides a window of opportunity to add such mulching films to the list of accepted polymers for soil improvement. A recent analysis, which already considered the implications of the COV19 pandemic, estimates the global CAGR for BDO with 6.2% and within Europe forecasts a 4.4% CAGR.

EU BIOREFINERY DEPLOYMENT

ADDITIVES

Propylene glycol (PG)

The he main use for PG is in unsaturated polyester resins, as de-icers and antifreeze agent. It is applied in the chemical, pharmaceutical and food industry. Its ability to absorb water and maintain moisture is a relevant characteristic used in medicines and cosmetics. Bio PG is produced from hydrogenolysis of glycerol (pathway C) or sorbitol (pathway B).

PERFORMANCE

Bio-based PG can be produced 100% bio-based by using oil-based or starch-based crops. The feedstock use is regionally specific, along with vegetable oils, palm oil and soy oil are the cheapest, but controversies are related to their production. LCA show a significant reduction of GHG emissions comparing bio-based with fossil-based PG. The production of the feedstock used has the highest impact related to climate change. The toxicity of PG is very low. It provides a good alternative for environmentally sensitive antifreeze, coolant/heat transfer applications. Technical performance is identical with fossil-based PG and it can be produced cost competitively.

DRIVERS AND BARRIERS

Driver

- Objectives to reduce GHG emissions and avoid fossil feedstocks

Barrier

- Reduced policy support for biodiesel and critical view on palm oil and soy as main feedstocks decrease availability of PG

ROADMAP ACTIONS

Bio-based propylene glycol can be produced by pathways B or C. The roadmaps for these pathways include actions for stakeholders to take to scale up these pathways including the production of propylene glycol.

MARKET OUTLOOK

PG is largely produced as a side product from biodiesel production. Feedstock such as palm oil or soy will be phased out under RED II, which will further decrease biodiesel production. The use of PG as sustainable bio-based coolant might drive the demand. Estimations for the CAGR for PG are between 4-7% (see case study) for the global market, which is within the line of the low scenario for the building block product group

EU BIOREFINERY DEPLOYMENT