VANGUARD INITIATIVE
New growth through smart specialisation

Bio-economy pilot

Case for joint-demonstration "Biobased Aromatics "
Leader: Flanders; Co-Leaders: South Netherlands, NordRhein Westfalia, ;; ,

Concept Note

- Description of the application(s) envisaged, with detailed description of the specific application

The potential uncertainties of availability of fossil resources as a source for transport fuels, chemicals, and energy is driving the transition of our economic model towards other feedstock. The concern about greenhouse gas emissions drives us to a more sustainable bio-based economy as part of the circular economy. Following this strategy, the use of renewable resources and the production of industrial (bio)chemicals in a biorefinery approach contribute to a large extent to climate change mitigation, environmental protection and safety. This conversion of renewable biomass feedstock into a variety of chemical products reduces the dependence on oil imports and creates new opportunities for more safe, environmental friendly, circular economy-based and more performant molecules leading to innovative materials and products.

Chemicals, and in particular, aromatics represent a significant share of our today's chemical building blocks (> 40%). Taking only the benzene-toluene-xylene (BTX) market into account for 2012, a total volume of 100 Mio tons was reached (Weastra estimation based on secondary market research). In parallel, the price of aromatic molecules strongly increased in 2012 (> 25%), and the market is expected to further grow by 4 to 8% till 2020. The change in the US to shale gas and some scarcity in China for xylene **makes that a certain scarcity (up to 5 million tons in 2020) of aromatic molecules can be expected on the market (PWC-2013).**

On the other hand now a day for several reasons lignin is an abundant, often not used biomass. Due to its complexity, up to now this feedstock was nearly not used. Nowadays several new developments make that lignin is becoming a very challenging feedstock with high potential not only as drop in but even more for innovative molecules. Additionally it can be mentioned that using this biomass may lead to GHG-emission reduction as otherwise slowly the lignin is leading to CO_2 and CH_4 emission just by lying in nature or in deposits. Apart from lignin also sugars from lignocellulose approach can be used via conversion into functionalised molecules via fermentative and chemical processes.

A strong part here can be a phenol-based chemistry and a furan-based chemistry.

In the Vanguard Bioeconomy Initiative it was decided to set up a Joint Demonstration on Lignin valorisation to aromatics. Attention is paid to different biomass-lignin sources (S, G, H), different processing methods, different hydrolysis methods, different separation and purification methods. Different modifications and polymerization approaches will lead to innovative molecules and materials. Also attention can be paid to upscaling and analytics.

The members of this Joint Demonstration are invited to indicate on what they are working, on what they are collaborating (in other projects and other consortia) and what they are missing to bring this Demonstration to the market and to make Europe key in the business of new biobased aromatic molecules.

- Assessment of the "distance-to-market" (TRL 5, 6, 7 or 8) and of the business potential for the own companies.

The activities on bio-based aromatics are at the moment operating at the TRL of 4 to 5. The Biorizon (Initiative between the Netherlands and Flanders) consortium has submitted a proposal on higher scale production of innovative biobased aromatics in order to provide the companies with the necessary amounts to set up their testing. So, that will bring the TRL to 5. A BBI project proposal is submitted to produce even larger amounts of materials bringing the TRL near to 6.

- Description of the key assets of the regions participating

At the moment many projects are ongoing in the field of sugars to aromatics and in the field lignin to aromatics. On top of that 2 demo- or upscaling projects were submitted and wait for approval.

Next steps are:

- **techno economical assessment**
- **evaluation of REACH for the innovative lignin-based molecules**
- **development of new applications (together with end users)**
- **full development of the value chains**

The following companies are involved in one of the projects:
Sita, Cobalin, Beaulieu, Lawter; Foresa, Agfa Gevaert, AEB, Orgaworld, Aterro, Avantium, Global yeast, TFC, Chemstream, Cobalin, Technaro; AEP Polymers, Metsä, Kottka Mills, Wood Kplus, Andritz, Prefere resins, UBE.
Besides more than 20 companies are also on the list of advisors and stakeholders. A few examples: Sappi, Taminco, Total, Ineos, Solvay, DSM, Sabic, Omnichem, Bayer, ….

- What is the added value of **joint** demonstration activities here?

The added value is in the full development of the value chain from biomass or waste up to molecules and further to end user materials, polymers, resins etc.
Depending on the biomass that is used (cereals-straw, grasses, hard wood, soft wood, …) the lignin will be dominated by coniferyl, sinapyl or coumaryl groups. In some cases these are more a mixture, in other cases these are nearly pure one of the groups.
The lignin is composed of about 10 different bonds (ether and carbon-carbon) leading easy of difficult degradation. Genetic modification or modern plant breeding technology (e.g. protoplast fusions) can lead to next species with altered composition allowing a better processing and leading to lower differentiation after hydrolysis.
Lignin can be available as protolignin (original lignin in the plant) or after processing as a kind of side stream or waste. The waste can be fresh or deteriorated (i.e. weathered).

Biomass-processing defined sources of lignin

The most well-known lignin sources are Kraft lignin and lignosulfonate both coming from the conventional pulp and paper processes. These sources are abundantly available, but contain sulphur, putting strong restrictions on the further use especially via catalysis.
Old lignin sources, as a result of wood ethanol production in the past are named hydrolysis lignin. It is known that in some places, millions of tons are stored leading sometimes to fires. The composition is not very well known.
The 2G ethanol production is based on several biomass pre-treatment processes (steam explosion, ammonia treatment, acid treatment, pressure and temperature treatment, etc.). Lignin, as a polymer, is released but the compositions depend on the cellulose-hemicellulose pre-treatment.
Special treatments were developed to make lignin as well as organosolv, Lignoboost, etc. The direct attack or 'lignin first' method leads to protolignin hydrolysis accompanied by cellulose and hemicellulose pulp release. An innovative method is the extraction of lignin via ionic liquids leading to a severe recovery or recycling to the IL afterwards.
The Superheated Steam Method delivers also a quite pure lignin. The method of LignoForce™ is based on black liquor acidification with CO_2 and an oxidation step. The Triversa Process™ converts biomass into furfural, cellulose and native lignin. β-valerolactone needs to be recycled.

Hydrolysis of lignin

Lignin can be hydrolysed chemically (acid-based or alkali-based) and enzymatically. In this last case many different enzymes can be used and lead to several different monomers, oligomers and changes in functional groups.
Apart from hydrolysis it can be cracked (catalytic under pressure and temperature), oxidized or reduced.

Separation and purification of lignin fragments

The final applications of lignin fractions will depend strongly on the economical viable separation and purification processes that can handle large volumes and fractions. Finally processes as crystallization and distillation will be needed to provide the necessary purity. It can specially be mentioned that colour removal is a big hurdle in order to lead to a breakthrough of several lignin applications.
After further modifications, a second separation and purification step will be necessary as well also at the level of polymers and materials.

Applications and modification of lignin-based molecules

Lignin, especially after purification, can be used as fibre or as source for monomers, oligomers and smaller polymers.
High molecular weight lignin fractions can be used to develop super strong nanofibers, whereas the lower MW-fraction can be used in more general applications or further hydrolysed. It is clear that mixtures and separate molecules can be used, depending on the application. As well monomers, oligomers and smaller polymers do have their place in the applications. At the level of oligomers a difference can be made between low and higher molecular weight oligo's with different applications.
De- and refunctionalisation can be done in order to change characteristics and to allow polyester or polyether formation. Reactions with other bio-based molecules and or CO_2 might be as well opportunities. Chemical, enzymatic, microbial, (bio)electrochemical etc. methods can be applied.
We can mention some applications: fire retardants, antioxidants, polyurethanes, phenolic resins, wood plastic composites, surfactants, dispersants, coatings, flocculants, fertilizers, aromas & fragrances. These molecules can be used in: automotive industry, tyres, plywood, laminates, textile industry, pharmacy, cosmetics, plastics, agriculture, furniture & construction, adhesives, paints, inks, polymers (polyurethanes, polycarbonates, polyamides, …), pulp & paper, feed, …

Upscaling

Essential in the approach is the upscaling. Most of the products and molecules are new and unknown. The many end-users and brand owners are very much interested to test the performances of these new molecules and mixtures. In order to get their full support now it is necessary to be able to provide not grams but hundreds of grams, kilograms etc. Therefore from the development now on, we need reactor and fermenter equipment that lead to this scale (at least kg scale) followed by adapted separation and purification equipment.

Analytics

As we speak about new molecules and new polymers, analytical tools will as well be necessary to support the development and to identify the right functionalities and material characteristics.

Environmental and safety issues

One of the goals is to make new materials with less toxic emission or based on safer production processes. In this way evaluation of ecological and human toxicity or impact, safety issues, emissions of the new materials, will be necessary also in function of REACH in case the molecules are modified. In order to verify the overall sustainability, LCA-studies will be necessary.

- Description of a first set of common demonstration activities.

Common demonstration strategies are set up via two project proposals only dedicated to upscaling and not to development. This is and INTERREG project and a BBI-project. We need more set ups in this field as several feedstocks and pretreatment technologies can be used. The different approaches will lead to different molecules and different functionalities and applications.

- Who would be interested to join the case?

The Joint-Demonstration on Biobased aromatics aims to bring together the knowledge and experience in Europe on feedstocks, its pretreatment, its fractionation into sugars, lignin and others, it hydrolysis followed by separation, its functionalization and its

integration into new polymers and products via several regional based demonstration plants either at the upstream level, either at the downstream level, either at the product level. Especially this 'product' level is seen as the big challenge for Europe and for the regional participation via many consumer product producers including large companies and SME's.

It will not be possible to generate the full value chain in just one region. Therefore we need this Joint-Demonstration to make full value chains from feedstock to market.

We see several regions with relevant competences along the value chain and also regions that already are involved via one of the approved and ongoing projects. Also nearly each vanguard region is home to brand owners or consumer products producers that could be interested in novel aromatics applications and could become involved.

The different competences present in the Vanguard network (different feedstocks expertise, value chain positions, end user industries) can give rise to multiple projects for joint-demonstration.

Interested partners and regions could be:

- Agricultural regions with excess biomass (produced on purpose or as residues)
- Forestry regions with large excess of forestry residues or willing to invest in new biorefineries
- Feedstock providers (including pretreatment, compacting, shredding etc.)
- Chemical regions interested to invest in setting up new production sites or in refurbishing existing plants
- Biotech regions (companies) interested to set up a productions site
- Regions with material developers including large companies and SME's in the higher mentioned domains (maybe also other domains can be added)
- Regions with a strong emphasis on technology development and process intensification
- Regions involved in REACH, LCA, certification etc.
- Regions involved in special chemicals and pharmaceuticals or food substances (nutraceuticals, anti-oxidants, …)
- Regions involved in feed production and additives
- …