VinylPlus Status Report on Renewable Raw Materials

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SUSTAINABLE DEVELOPMENT

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EXECUTIVE SUMMARY

Amongst the five 'challenges' addressed by VinylPlus as part of its 2011 commitments, VinylPlus committed to publish a renewable materials status report which was done in 2015. The present version is an update of the 2015 report. It presents relevant information as available in mid-2020 and constitutes an input to the 2021 review of all VinylPlus voluntary commitment targets.

This VinylPlus commitment is in line with EU policies striving to develop renewable raw materials, the latest being the 2018 update of the Bioeconomy Strategy. Enthusiasm about use of renewable materials in the early years of the present century has given way to more balanced views from stakeholders. Some leading sustainability NGOs, like the Natural Step, advocate the need to ensure that the move into renewables is made in a responsible manner. Some EU environmental NGOs even stress potential negative impacts including limited availability of biomass feedstock, land degradation and loss of natural habitats, increased levels of pollution and land conflicts. They recommend assessing carefully the environmental and social impacts of 'bioplastics' over their entire lifecycle.

The EU chemical industry stresses the opportunity offered by the 'bioeconomy' to diversify the chemical industry's raw material base, while reminding that renewable raw materials only contribute to a sustainable development if they are also advantageous from environmental and social aspects, beyond technical and economic feasibility. The plastic industry reminds of the necessary trade-offs and advocates that sustainability, underpinned by lifecycle thinking, must play a major role in developing bio-based plastics.

PVC products are made of PVC resin and additives. Regarding switch to renewable raw materials, the focus should be on PVC resin and plasticisers, representing together the largest amount of carbon in PVC products. The source of the 57% chlorine content of PVC resin (common salt), although not renewable in the strict sense, is almost inexhaustible, which significantly limits the fraction to be potentially sourced from renewable raw materials.

The production of PVC resin from biomass is not hampered by major technical issues. Ethylene produced from biomass via ethanol has the same characteristics as ethylene produced from oil or gas, and there is absolutely no difference for the quality of the produced resin.

There is some evidence that the use of biomass helps to reduce CO_2 emissions due to capture by the plants, but the overall environmental assessment results very much depend on the impact of transport from the fields to the facilities for ethanol and ethylene production, the impact on potential deforestation, agricultural land use and biodiversity.

Several projects to produce PVC from renewable resources were initiated or announced before 2010 in Brazil, Egypt and India. Most if not all appear to have been scaled down or cancelled in the following years, mainly for economic reasons.

In 2019 and 2020, two EU PVC producers announced the commercial launch of bio-attributed PVC resin grades. Although technically suitable for all applications, they are expected to mainly serve demanding customers in highly specialised markets. Both companies claim that their bio-attributed PVC reduces CO_2 emissions by more than 90% compared to conventionally produced PVC, with no loss of properties.

In the case of bio-attributed feedstocks, the renewable feedstock might not be physically traceable throughout the production processes, i.e., the actual carbon molecules in the chosen chemical/plastic may not be bio-based, but the use of the renewable feedstock and the corresponding attribution to certain amounts of chemicals/plastics can be verified through third-party certification in a fully transparent and auditable way.

Bio-based plasticisers have grown in importance in the past few years due to increasing challenges about climate change and sustainability, and concerns regarding the potential hazards of conventional plasticisers. The most usual raw materials are oils extracted from castor plant, soybean, palm, rapeseed, sunflower, linseed but also starch. Several bio-based plasticisers are already commercialised. Their performances are similar to those of traditional plasticisers.

Other bio-sourced plastics are slowly entering the market, currently accounting for about 1% of the total polymer demand. A Brazilian company operates a 200 kt/y polyethylene plant produced from sugar cane, retaining the same properties, performance and application versatility as polyethylene from fossil origin.
It also produces ethylene vinyl acetate copolymer from sugar cane. Other major petrochemical companies however delayed projects to produce PE from sugarcane.

The economics of bioplastics production has come into question because of the sustained availability of inexpensive fossil sources, including shale gas feedstock. Developments are therefore happening more in the field of speciality chemicals and plastics. Companies in France and Italy are for example developing plastics sourced from starches, cellulose, vegetable oils, etc., mainly for specialised uses in packaging and disposable items.

The barriers to extending use of renewable raw materials for the production of plastics are indeed essentially related to economics and to the limited availability of bio-sourced petrochemicals, impacted on the one hand by competition with food and feed crops, and heightened concerns about deforestation, and the availability of cheap oil and gas on the other hand. A lowering of the economic barrier was expected, due to an anticipated steady cost increase of oil and gas, but this did not happen, partly due to the rise of shale gas and partly because the development of renewable energy lessened demand. The latter is a consequence of the increasing focus on climate change, which pushed concerns about dwindling availability of oil and gas to the background. Replacing non-renewable carbon in plastics is potentially less economic and less eco-efficient than replacing non-renewable carbon in energy production by solar panels, windmills and other carbon-free technologies. As a result, concerns about oil and gas have actually moved from limited availability to low demand, i.e., from 'peak oil' to 'stranded assets'. The recent collapse in oil prices due to the Covid-19 pandemic reduces even further the economic incentive for switching to renewable raw materials in the short term.

Despite all the obstacles, VinylPlus shares the views of industry associations and NGOs about the benefits of developing renewable raw materials, provided it achieves more sustainability. A globally agreed comparative sustainability assessment methodology should be developed, including all sustainability aspects (CO_2 emissions, other environmental impacts, agricultural land use, deforestation, transport, external costs, etc.).

In the present circumstances, only few companies will undertake a major switch to renewables due to concerns about putting their financial sustainability at serious risk. Overcoming the barriers would require political will at global level implemented in concrete and effective policies to:

- Support R&D to develop renewable resources which do not compete with food and feed and which can eventually achieve economic sustainability.
- Internalise the environmental costs of non-renewable raw material sources, based on an accepted methodology for comparative sustainability assessments.
- Implement rational incentives to purchase bio-based products, for example via public procurement guidelines, when their sustainability advantages can be clearly demonstrated.

Significant political decisions would be needed to ensure a rapid switch to renewable raw materials, but they would require global agreements which are still unlikely because of the differences in the economic development and the production potential of the various world regions. Renewable raw materials are therefore likely to remain in the short term limited to niche markets, where the eco-friendly image of the products compensates higher prices.

Finally, taking the broader perspective of saving non-renewable resources, the potential of recycling should not be underestimated. Regarding depletion of the non-renewable raw materials, recycling achieves the same objective as switching to renewables, and even saves renewable raw materials. In addition, recycling helps to reduce energy consumption, and reduces use of incineration and landfilling. Because of its recycling potential and its technical characteristics, PVC is definitely well positioned in this aspect.

Using renewable raw materials as fillers (e.g., wood dust or rice husks) in PVC compounds, as well as extending the useful life of PVC products, are alternative ways to save (renewable) resources which merit to be reminded as well.

The social aspects of the potential move to renewables have not been covered in this report.

1. CONTEXT

1.1 VinylPlus Commitment related to the use of renewable raw materials

The VinylPlus voluntary commitment of the European PVC Industry[1] followed the Vinyl 2010 voluntary programme and was published in June 2011. Amongst the five 'challenges' addressed by VinylPlus, several sub-commitments were made regarding the use of renewables (renewable raw materials), in particular:

- Setting up a renewable materials task force (TF). In order to develop a plan to increase the use of renewable raw materials, if they are sustainable. VinylPlus set up the TF to coordinate the discussion across the PVC value chain integrating relevant stakeholders and upstream manufacturers.

- Publication of a renewable materials task force status report by end 2012. This proved to be more time-consuming than anticipated, delaying publication until 2015.

The present report is an update of the 2015 one, with a slightly modified structure. It presents relevant information as currently available and constitutes an input to the 2021 review of all VinylPlus voluntary commitment targets.

It is important to mention that this report, as well as its previous version, does not address the renewable energy issue, which is a specific topic to a large extent outside the control of the PVC industry.

1.2 Definitions of renewable raw materials

There is no single official/legal definition of 'Renewable', but a common understanding of the meaning of the word nevertheless appears to exist.

A general definition is given by Whittow,[2] i.e., "*Resources that have a natural rate of availability and yield a continual flow of services which may be consumed in any time period without endangering future consumption possibilities as long as current use does not exceed net renewal during the period under consideration.*"

Another, more restrictive, definition is: "*A renewable raw material (RRM) is a material of plant, animal, or microbial biomass, which are based on the photosynthetic primary production and are used by man outside the food and feed area for material or energy production*".[3] Hence this applies in principle exclusively to an organic material.

Another useful definition can be found on Investopedia,[4] opposing 'renewable' to 'non-renewable', and extending the scope to 'resource', not only 'material':

'Renewable Resource': *"A substance of economic value that can be replaced or replenished in the same amount or less time as it takes to draw the supply down. Some renewable resources have essentially an endless supply, such as solar energy, wind energy and geothermal pressure, while other resources are considered renewable even though some time or effort must go into their renewal, such as wood, oxygen, leather and fish. Most precious metals are considered renewable as well; even though they are not naturally replaced, they can be recycled because they are not destroyed during their extraction and use."*

'Non-renewable Resource': *"A resource of economic value that cannot be readily replaced by natural means on a level equal to its consumption. Most fossil fuels, such as oil, natural gas and coal are considered non-renewable resources in that their use is not sustainable because their formation takes billions of years".*

1.3 Relevant policies

Most EU policies are directed towards renewable energy rather than renewable raw materials. As however stated on DG GROW's web page **https://ec.europa.eu/growth/sectors/raw-materials_en** *"Securing a sustainable supply of raw materials is a key priority for the EU."* The following policies are relevant for raw materials:

1.3.1 Lead Market Initiative

The Commission presented in 2007 an initiative on lead markets. It was the first EU's **strategic policy framework.** Six markets were identified, including 'recycling', 'bio-based product' and 'renewable energies'.[5]

The document mentions:

• *"Bio-based products are made from renewable, biological raw materials such as plants and trees. The market segment chosen for the specific LMI includes non-food new bio-based products and materials such as bioplastics, bio-lubricants, surfactants, enzymes and pharmaceuticals. It excludes traditional paper and wood products, but also biomass as an energy source.* ***The long-term growth potential for bio-based products will depend on their capacity to substitute fossil-based products and to satisfy various end-used requirements at a competitive cost, to create product cycles that are neutral in terms of greenhouse gas (GHG) and to leave a smaller ecological footprint, i.e., generating less waste, using less energy and water.*** *Europe is well placed in the markets for innovative bio-based products, building on a leading technological and industrial position.*

• ***Recycling reduces waste going to disposal, consumption of natural resources and improves energy efficiency.*** *It therefore plays an essential role in the move towards sustainable consumption and production – not only in terms of energy but in terms of all resources we produce".*

A report from the Ad-hoc Advisory Group for Bio-based Products in the framework of the Lead Market Initiative (3 November 2009)[6] includes recommendations to promote bio-based products, as summarised below:

Legislation promoting market development

• *The biological/bio-based carbon contained in biobased products shall be deducted in the calculation of the total CO_2-equivalent emissions of the products.*

• *Consider setting indicative or binding targets for certain bio-based product categories, drawing on the experience from biofuel quotas in the EU.*

• *Allow Member States to reduce taxes for sustainable bio-based product categories.*

Product-specific legislation

• *Allow bio-based plastic to enter all waste collection and recovery systems, including composting, recycling and energetic recovery (depending on the type of plastic and compliance with applicable standards). Bio-based plastics certified compostable according to EN 13432 should gain unhindered access to biowaste collection.*

• *Study the possibility of mandating the use of bio-lubricants and hydraulic fluids in environmentally sensitive areas. This could be implemented e.g., via soil protection and water protection legislation.*

• *Bio-based construction materials (foams for insulation, composite material, mortar, and concrete made of vegetative aggregate particles) have now become sufficiently advanced to offer a real alternative. The Construction Products Directive should promote the specificities of bio-based products. In addition, new and transparent standards showing the product capabilities are needed to help demonstrate that bio-based materials comply with construction legislation.*

Legislation related to biomass

• *Legislation and policies must allow renewable raw materials for industrial use to be available in sufficient quantity of good and guaranteed quality and at competitive price.*

• *Increase investments in developing and optimising infrastructures and logistics for an optimal use of all available biomass (including waste)*

Encourage Green Public Procurement for bio-based products

• *Encourage contracting authorities in all EU Member States to give preference to bio-based products in tender specifications. A requirement or a recommendation to give preference can be laid down in a national action plan adopted by the government.*

• *Preference should be given to bio-based products unless the products are not readily available on the market, the products are available only at excessive cost, or the products do not have an acceptable performance.*

Standards, labels and certification

• *Develop clear and unambiguous European and international standards. The standards will help to verify claims about bio-based products in the future* *(e.g., biodegradability, bio-based content, renewable carbon, recyclability, and sustainability).*

- *The sustainability assessment should be based on all three pillars of sustainability: environmental, social and economic. While we need (to develop) tools to assess sustainability of products, we need to ensure the tools used will stimulate and not limit the development and implementation of bio-based products.*

- *Begin a reflection process on what types of specific product labels are suitable for bio-based products and what information to be given to the consumer.*

Regarding the markets for bio-based products, the report mentions:

The Bio-based Products Lead Market covers a broad range of intermediate products, product components, and ready-made products, e.g., bio-based plastics, bio-lubricants, bio-fibres for textiles, composite materials for construction and automotive, chemical and pharmaceutical building blocks, organic acids, amino acids, and enzymes. Biological raw material from plants and trees, or waste, is renewable in the short term (less than 10 years), as opposed to fossil material renewable in 10 million years. Bio-based products can thus make a sizeable contribution to CO_2 reductions.

There are already several bio-based products on the market in Europe; for instance, the chemical industry is estimated to use 8-10% renewable raw materials to produce various chemical substances.

In other market segments, the market shares for bio-based products are still very low. Europe has a few small companies specialised in bio-based products and several major chemical companies developing bio-based applications.

The aim is to enhance market demand for eco-efficient bio-based products, in order to exploit the positive environmental impact of bio-based products. A limited availability and increasing relative cost of fossil resources are driving factors for an increased demand for bio-based products in the EU, as well as policy developments intended to mitigate climate change and promote sustainable production and consumption.

In addition, bio-based products may offer specific innovative properties that have advantages over other products. For example, in sensitive environments, hydraulics and chains can use biodegradable lubricants that are non-toxic to soil and water.

An evaluation report on the progress made, drafted by independent experts (Centre for Strategy and Evaluation Services–Oxford Research) on the first round of the LMI was presented in July 2011.[7] It highlighted that:

- *In order to make progress, four different categories of policy instrument have to be prioritised including:*
  - *Legislation proposals (new legislation or modifications) and regulatory measures to coordinate regulation that will foster innovation and remove regulatory burdens and obstacles to innovation.*
  - *Promotion of the use of public procurement to foster the uptake of innovative products and services.*
  - *Development of more consistent standardisation, labelling and certification to encourage the diffusion of innovative practices and facilitate the development of lead markets.*
  - *Other complementary actions to support the impact of the above instruments including business and innovation support services or financial support instruments for supply side activities.*

- *Over the period 2007-2011 some progress was made regarding bio-based products:*
  - ***Bio-based products:*** *With the co-operation of the European Committee of Standardisation (CEN), several new standards were produced that support the sector to work towards common innovative product goals. … However, several policy barriers that restrict growth remain in place. If the industry is to achieve sector-wide competitiveness on a par with other regions such as the U.S. and China, stakeholders have requested that the European Commission appropriately align and develop the sector through its broader innovation, agricultural and research policies.*

1.3.2 Subsequent developments

The European Commission later launched initiatives such as **The European innovation partnership on raw materials** and the **EU blueprint for EU forest-based industries**

The European Commission adopted in February 2012 a strategy to shift the European economy towards greater and more sustainable use of renewable resources.[8] Due to world population growth and limitations on the availability of natural resources, Europe needs renewable resources for secure and healthy food and feed, as well as for materials, energy, and other products. This Commission's strategy and action plan, ***'Innovating for Sustainable Growth: a Bioeconomy for Europe'***, outlined a coherent, cross-sectoral and inter-disciplinary approach to the issue, including the sustainable use of renewable biological resources for industrial purposes, while ensuring biodiversity and environmental protection. The plan focused on three key aspects: developing new technologies and processes for the bioeconomy; developing markets and competitiveness in bioeconomy sectors; and pushing policymakers and stakeholders to work more closely together.

The Commission's proposal was one of the operational proposals under the **Innovation Union** and **Resource-efficient Europe** flagships of the EU 2020 strategy. The need to increase public funding for bioeconomy research and innovation was recognised under the Commission's research programme Horizon 2020.

This Bioeconomy Strategy was updated in 2018. The update proposes an action plan with 14 concrete measures to be launched in 2019. One of the five stated objectives is *"Reducing dependence on non-renewable, unsustainable resources whether sourced domestically or from abroad*". In addition to research and innovation grants under the 'Horizon 2020' R&D programme, the EU announced deployment of a targeted financial instrument – the €100 million Circular Bioeconomy Thematic Investment Platform to de-risk private investments in sustainable solutions. Several policy and informative documents can be downloaded.[9]

It reported that the 'Bio-based chemicals and pharmaceuticals, plastics and rubber' sector employs 400,000 people in the EU, generating a turnover of €177 billion. Among these documents a booklet describes priorities and EU-funded research projects.[10] The accompanying staff working document states that "*the EU bio-based chemicals market is diverse and large differences can be found between product categories. For example, the bio-based solvents and platform chemicals both have a very small bio-based percentage, while on the other hand, surfactants and cosmetics already enjoy a large bio-based share.*"

2. INFORMATION, POSITIONS AND STUDIES BY INSTITUTIONS, NGOs, INDUSTRY ORGANISATIONS AND ACADEMIA

2.1 EU institutions

A working paper prepared by the European Topic Centre on Sustainable Consumption and Production for the European Environment Agency (EEA) was published in March 2010.[11] The EEA wanted to support the sustainable use of natural resources and further develop sustainable consumption and production patterns in the production sector. A broader use of renewable raw materials (RRM) and the substitution of fossil-based materials and products by RRM could be an important step to that goal.
The study gave an overview on the industrial material use of RRM in Europe and a preliminary assessment of the environmental aspects of RRM. It confirmed that the environmental impacts of RRM are highly complex. Further research on the environmental implications of RRM was therefore needed to provide a more sophisticated basis for political deciders. The study confirmed the absence of accurate data for the whole of Europe, leaving only rarely updated estimations based on expert interviews. **One of the key conclusions was that one of the most promising innovative bio-based products are bioplastics.**

A research paper published in 2012 includes considerations related to ethanol and to cost.[12] Herewith a relevant quote:
"no discussion of bio-based or RRM would complete without discussing ethanol. Ethanol represents one of the most successful uses of RRM the world has seen. As of 2010, less than 10% of world ethanol production for industrial use was produced by chemical synthesis from crude oil or natural gas (Jering and Gunther, 2010). Biotechnical ethanol production is the large-scale fermentation using agricultural biomass as feedstock (sugarcane, sugar beet, or starch plants such as corn), followed by purification of the resulting ethanol by distillation (McLaren and Faulkner, 2010). Ethanol is then used to produce fuels, medicines, colourings, scents, flavourings, solvents, and a host of other products (Jering and Gunther, 2010).
In all of the readings and government reports I saw, cost was never really brought up. Considering the growth of plant-based products in place of petroleum, and the fact that the continents of Europe and Africa are ahead of North America in their use and production of bio-based product, cost does not appear to a huge consideration. Considering myself and many people I have spoken to, most of us would be willing to pay a little more for a bio-based product that was considered 'green'."

2.2 NGOs

The Natural Step (TNS)'s briefing note on Renewables of April 2014, prepared for VinylPlus (ANNEX), aimed to identify possibilities for progress in the implementation of the VinylPlus renewables programme. It mainly highlighted the absolute need to ensure that the move into renewables is made in a responsible manner:

"**Responsible biotechnology** – the emergence of biofuels highlighted issues like food vs fuel and a shift into renewables as feedstocks will raise similar questions around trade-offs and unintended consequences. We have only recently seen evidence of well-thought-out plans for responsible biotechnology and would like to present the following guiding principles as an example of the types of considerations that should be made when moving into renewables:

1. *Aim to achieve substantial societal and environmental benefits, as well as business benefits.*
2. *Support regulatory and governance structures that put public interest and private gain on equal footing and promote extensive stakeholder engagement.*
3. *Avoid adverse impacts on food security and affordability.*
4. *Secure demonstrable, substantial reductions in greenhouse gas emissions.*
5. *Commit to production systems that optimise conditions for biodiversity and healthy ecosystems.*
6. *Commit to manufacturing processes that maximise the value of all feedstocks (e.g., closed-loop systems).*
7. *Place no additional burdens on the availability of scarce water supplies.*
8. *Avoid any risk of gene transfer in the open environment.*
9. *Pose no threat to human health.*
10. *Achieve the highest standards of health and safety both for workers and surrounding communities".*

In 2017, several EU environmental NGOs published a joint position paper titled 'Bioplastics in a Circular Economy: The need to focus on waste reduction and prevention to avoid false solutions'.[13] Objections presented in this paper are directed towards claims about the benefits of bio-degradable plastics rather than bio-sourced plastics. The paper however also stresses the *"limited availability of biomass feedstock"* and goes on stating *"It is predicted that as a result of the rise in global production capacity of bio-based plastics, around 1.4 million hectares of land for feedstock will be required by 2019, more than the size of Belgium, the Netherlands and Denmark combined. Only 5% of global production is expected to take place in Europe, with 81% taking place in Asia, where related production impacts include land degradation and a loss of natural habitats, reduced water quality, increased levels of pollution and land conflicts. Thus, the accelerating European market demand for bioplastics will continue to contribute to these negative externalities."*

Some of their policy recommendations in this joint position are:

- *"Prioritise plastic prevention and overall reduction: substantially reduce the use of excessive, unnecessary and throwaway plastics by systematically directing all relevant policies towards waste prevention and the reduction on overall plastic use, including developing reduction targets, phasing out single-use items and disincentivising the use of non-durable plastics, independent of their feedstock or biodegradability claims.*

- *Assess impacts of bioplastics: carry out a scenario analysis and impact assessment on the potential impacts, quantitative and qualitative, which the substitution of plastic feedstock from fossil to biomass sources would have on the environment and society throughout the full lifecycle".*

Other NGOs express scepticism whether bio-based plastics help achieve sustainability goals. Health Care Without Harm, for example, recently wrote *"Reduction of plastic should be the priority – but this is not always technically feasible in the healthcare sector where plastic products are used in important procedures. In such cases, when procurers are considering replacing plastic items with alternative, more sustainable materials, we must be careful to not fall into the trap of thinking that the term 'bio' automatically means a product is good for the planet".*[14]

2.3 Chemical industry

A Cefic's November 2010 discussion paper[15] stressed the *"huge potential to increase the share of bio-based chemicals, in line with the objectives set by the High-Level Group on the Competitiveness of the European Chemicals Industry and in the EU 2020 Strategy." It stressed "Given that industry cannot control many of the factors that play a role, it cannot commit however to any fixed targets. In order to reach the objective of increased use of sustainable feedstock, industry realizes that it needs to invest in bio-based R&D, process facilities, demo plants and eventually in production capacity. However, it should be a joint Public-Private Partnership or an Innovation Partnership Initiative effort and investment in which governments and the European Commission take like responsibilities. The EU needs to develop an integrated policy to stimulate a sustainable European bio-based economy, covering the full value chain; otherwise, that ambition will not be feasible. (…) Care needs to be taken that the bio-based products are not only green but also sustainable, and that market economy principles should prevail with supports compliant with the EC competition rules and State Aid guidelines. Indeed, whilst barriers to bio-based chemistry should be removed, this should not lead to new discrimination against fossil-based chemicals that have an equivalent ecological profile."*

Cefic's views further stressed that *"the Commission should develop and implement a coherent strategy and action plan to capitalize on European bio-based economy investments made hitherto. When developing policies, the EU needs to:*

- *develop legislation that removes discrimination of biomass for feedstock use and is targeted towards sustainability rather than green* ***only;***
- *support market development in order to ensure the concept is proven but stop at the pre-competitive level in order to let the* ***free market*** *mechanism find the appropriate balance;*
- *define standards, labels & certification (international sustainability assessments, labelling);*
- *encourage green public procurement for bio-based products while avoiding discrimination of products based on traditional feedstock having an equivalent ecological performance on the basis of Life Cycle Analysis; and*
- *finance/fund R&D and demo plants, e.g., bio-refinery demos.*

However, the key message is that Europe can only develop a robust bio-based economy when industry has access to sustainable renewable feedstock in sufficient quantities, of guaranteed quality and at competitive (world market) prices. Distortions caused by regulations favouring fuel and energy over feedstock use should be removed and import duties for bio-based feedstock should be as low as for fossil-based feedstock."

A Cefic position paper of October 2016[16] stresses the opportunity offered by the 'bioeconomy' to diversify the chemical industry's raw material base. It reminds that *"In order for Europe to play a key role in the global bioeconomy, adequate and coherent policies are needed to unlock its potential."* According to this paper, *"The bio-based share in 2013 of chemical industry in the EU-28 was 6% and 12% for organic chemistry".*[17]

Core statements in a German chemical association VCI (Verband der Chemischen Industrie e.V.) October 2012 document[18] were:

- *"Resource efficiency and sustainability are important guiding principles for the chemical industry. The use of renewable raw materials only contributes to a sustainable development where it is advantageous also from ecological and social aspects – beyond technical and economic feasibility.*

- *Chemistry needs renewable raw materials at competitive world market prices; existing trade obstacles should be reduced or eliminated.*

- *Further research and development efforts are required to open up new fields of application for the material use of renewables in the chemical industry. It is essential to have laws and regulations conducive to innovation so that research and market potentials can be utilised to the full.*

- *Innovation is a major lever for a broader material use of renewables. For this reason, actions by public administrations should focus more strongly on promoting research and development. By contrast, economic or fiscal steering instruments are unsuitable and cannot achieve the identified goals.*

- *For the future, an integrated political strategy for the various use path of biomass (energy, fuels and materials) should be striven for. This strategy needs to create equal competitive conditions and aim for sustainability of the various uses".*

VCI published an updated position in 2017.[19] It reminds that *"Renewable raw materials have been established for a long time in the chemical industry"* and that *"the chemical industry in Germany used 2.7 million tonnes of renewables in the year 2013."* The position explains and defends the **'mass balance'** approach, by which the volume of renewables is attributed (allocated) to selected products, according to their individual formulation.

A report dated from September 2020 by the German Institute for Industrial ecology on behalf of the German association of Chemical Industries evaluates among other pathways the production of synthesis gas by gasification of biomass, and the production of ethylene from ethanol based on sugar cane or other biological sources.[20] The amount of biomass necessary to supply the German chemical industry is evaluated at 6.8 Mt/year via the gasification route, yielding a CO_2 emission reduction of about 3 Mt/y. The ethylene route would require 4.8 Mt/y forestry biomass or 4.3 Mt/y sugar beets, resulting in a CO_2 emission reduction of about – 4.5 Mt/year. The report also assesses the potential of recycling and recommends using a mix of technology pathways.

A report published in September 2020 by the nova-Institute for Ecology and Innovation[21] stated that *"In the bio-based chemical and plastics industry alone, turnover amounted to around 60 billion Euro (in 2017) and generated over 180,000 jobs, while the bio-based share of the chemical industry in the EU-28 increased from about 5% in 2008 to 8% in 2017."*

2.4 Plastics industry

Most raw materials for the manufacturing of plastics originate in the chemical industry. The views of the plastic and chemical industries are therefore mostly aligned in this respect. The views of the plastics industry could be summarised as cautionary supportive.

An article in the 2014 issue of a trade journal[22] cautions that bioplastics can have a higher environmental footprint than oil-based plastics and some of the claims made by the bioplastics industry are misleading. Bioplastics have indeed a number of advantages, such as helping to increase resource efficiency and minimising carbon emissions. This argument does not take into account the non-renewable fossil fuels consumed and the CO_2 emitted by the machines used to clear the land, sow the seeds, harrow the land and transport the pesticides and fertilizers used to grow the crops, not to mention harvesting the crop and transporting it to the polymerisation factory and the running of the factory itself.

The February 2018 view paper of PlasticsEurope titled 'Bio-based plastics'[23] addresses the sustainability aspects of bio-based plastics in the following way: *"Agricultural feedstock (e.g., corn, sugarcane), but also waste biomass (e.g., forestry) or CO_2 are 'alternative feedstocks' to fossil primary material. The most widely claimed benefit of bio-based plastic is to reduce a final product's carbon footprint, due to the sequestration of CO_2 during the life of the plant. Life Cycle Analysis shows that the transition from petro-based to bio-based sourcing produces trade-offs, and can have e.g., land use impacts. Sustainability, underpinned by lifecycle thinking, plays a major role in developing bio-based plastics. However, the sustainability of bio-based plastics, economically and ecologically, is based on a variety of factors:*

1. *cultivation conditions of the biomass for the feedstock;*
2. *technological maturity: as biomass production practices develop and processes become more energy and resource efficient;*
3. *region or country specific regulations;*
4. *a broad range of impact categories, as described, for example, in the 12 principles of the Roundtable on Sustainable Biomaterials (RSB) meta-standard."*

2.5 Academia

It is not possible in the framework of this document to review all academic papers on renewable resources for producing plastics. A few are quoted in some other sections. It may be interesting to mention here a recent paper starting with the following statement: *"Plastics contain a complex mixture of known and unknown chemicals; some of which can be toxic. Bioplastics and plant-based materials are marketed as sustainable alternative to conventional plastics. However, little is known with regard to the chemicals they contain and the safety of these compounds."* and concluding *"A comparison with conventional plastics indicates that bioplastics and plant-based materials are similarly toxic. This highlights the need to focus more on aspects of chemical safety when designing truly 'better' plastic alternatives."*

3. FURTHER CONTEXT AND RELEVANCE FOR PVC MANUFACTURING IN THE EU

3.1 Current and expected PVC market perspectives

The plastics production in the EU is still below the pre-2008 crisis level, as shown in the chart below.

PRODUCTION OF PRIMARY PLASTICS EU

Source: Eurostat

This is due to several factors:

- The general economic situation in Europe
- Increasing share of primary plastics imports from non-EU countries due to lower production costs
- Competition in export markets becoming more and more problematic because of the difference of energy costs in the Middle East and in the U.S. (due to shale gas production) compared to the EU.

Regarding PVC specifically, the market situation is even worse (minus 23% for EU demand of PVC resin in 2019, compared to 2007) because of the still rather depressed situation of the building and construction activity in Europe. This hinders the ability and willingness of industry to invest in costly new developments.

3.2 Current sources of bio-ethylene

In 2015, bio-ethylene production facilities in India and Brazil provided around 0.5% of the overall ethylene capacity; the largest facility produced over 200 kilotons annually in 2015. Brazil and the U.S. were the major contributors due to their largest input in bio-ethanol production, accounting for over 22% and 62% of the overall production in 2015, with corn and sugarcane being respectively the major feedstocks.[24]

The limited word-wide supply, the fact that ethylene is not transported over long distances and the high production costs of bioethanol in Europe are still significant barriers to the availability of bio-ethylene in Europe.

3.3 Specific aspects and impacts of shale gas developments on the EU PVC industry

Cefic reported in 2018 that *"The US shale gas boom has triggered a massive build-up of new chemicals production capacity there". "Energy costs are the European industry's Achilles' heel, especially compared to the United States, riding on a shale gas boom. Advantageous energy and feedstock prices are a clear enabler of competitiveness. The shale gas boom in the United States has greatly reduced energy and feedstock costs. A clear indicator of this situation is the cost of producing ethylene".*[25] The difference of ethylene cash cost between Europe and North America was around 350 USD/tonne in the first half of 2018, according to a graph in the same report.

This was in contrast to earlier Cefic views, as expressed in its position paper of March 2013,[26] which considered shale gas as an opportunity for Europe due to its potential resources; this was before the push-back from European policymakers experienced in later years. This earlier paper already stressed the *"significant competitive advantage for the US industry."* Cefic considered at that time that the development of both indigenous and imported shale gas could make an important contribution and made recommendations to European and Member State Authorities to *"accelerate the responsible exploration and production of indigenous shale gas by avoiding the creation of unnecessary regulatory barriers".*

NGOs in general and Greenpeace in particular are opposed to shale gas exploitation for reasons which are developed in a statement from 2012.[27] In addition to environmental and safety concerns, their main argument is that savings in general and a significant reduction of CO_2 emissions provide the only viable path to an environmentally sustainable and healthy future.

4. ACTUAL CASES AND FURTHER OPPORTUNITIES OF SWITCHING TO RENEWABLE RAW MATERIALS FOR PVC

4.1. Production of PVC resin

4.1.1 Announcements from before 2015 and current reality

When the first version of this status report was published, some actual examples were identified, without claiming to be exhaustive. They showed that running PVC production plants based on bio-based ethylene is not only possible but had actually taken place.

- Chemplast Sanmar (flagship company of the Sanmar Group, India) commissioned in September 2009 a PVC project at Cuddalore, Tamil Nadu. The facility had an annual capacity of 221,000 tonnes of PVC. The company nevertheless later switched from bio-based feedstock to petrochemical feedstock as reportedly the economics were not working out in favour of the former. The company's website as dated from 2020 does not refer to bio-sourced ethylene.[28]

- The Sanmar Group acquired Trust Chemical Industries in 2007 (now TCI Sanmar Chemicals S.A.E.) located at Port Said, Egypt with the intent of setting up the world's first large green PVC producing plant, using ethylene partly sourced from sugar-based ethanol. This company's website dated from 2020 mentions indeed a 400 kt/a PVC manufacturing capacity[29] but contains no mention of bio-source ethanol.

- Solvay Indupa (Buenos Aires, Argentina), announced in January 2008 its intention to expand its PVC plant in Santo Andre, Brazil and to construct a sugarcane ethanol-based ethylene plant with capacity to produce 60 kt/y. The output would be used in the production of PVC. The expansion was expected to be completed by 2010. In January 2011, Solvay Indupa disclosed that it had resumed studies for its 'green' PVC project in Brazil, but that no decisions had been made regarding size and timing. After an attempt (blocked in 2014 by Argentina's stock regulator) to sell its entire shareholding in Solvay Indupa S.A.I.C. to Brazilan petrochemicals manufacturer Braskem, this shareholding was acquired in 2016 by Brazilian chemical group Unipar Carbocloro. It seems that its ethylene is sourced from Braskem. Braskem does produce part of its ethylene from bioethanol, but Unipar does not inform whether its PVC monomer is based on such ethylene.

In summary, it is likely that the former announcements about bio-based PVC production in India and Egypt are no longer corresponding to the actual situation, but some PVC produced in South America may indeed still be bio-based.

4.1.2 Recent announcements by PVC resin companies

INOVYN (**www.inovyn.com**) announced the commercial launch of its bio-attributed PVC resin during the October 2019 K fair in Germany.[30] "Manufactured at Rheinberg, Germany, BIOVYN™ is made using bio-attributed ethylene, a renewable feedstock derived from biomass that does not compete with the food chain. BIOVYN™ is certified by The Roundtable on Sustainable Biomaterials (RSB, **www.rsb.org**) as delivering a 100% substitution of fossil feedstock in its production system, enabling a greenhouse gas saving of over 90% compared to conventionally produced PVC.

BIOVYN™ is expected to have numerous value-added applications across a range of industry sectors, including highly specialised end-uses such as automotive and medical.

INOVYN has been working closely with flooring manufacturer Tarkett (**www.tarkett.com**) since the early stages of product development. The first application of BIOVYN™ will be by Tarkett, who will source it for a new flooring collection."

This news was followed in February 2020 by announcement of a long-term supply agreement with Helsinki-based UPM Biofuels. The PVC uses residue from wood pulp manufacturing called UPM BioVerno, which has also been used to make bio-attributed polyolefns.[31]

In February 2020 VYNOVA (**www.vynova-group.com**) launched a range of bio-attributed PVC resins manufactured using renewable ethylene produced from certified second-generation biomass feedstock which does not compete with the food chain. The renewable ethylene is supplied by SABIC from the company's production facilities in Geleen (the Netherlands) and forms part of TRUCIRCLE,™ SABIC's portfolio of solutions that include design for recyclability, mechanically recycled products, certified circular products from feedstock recycling of plastic waste streams as well as certified renewables products from bio-based feedstock.

VYNOVA's bio-attributed PVC portfolio is available for both rigid and flexible applications and includes a wide range of K-values. The new range of PVC resins will initially be manufactured at the VYNOVA sites in Beek (the Netherlands) and Mazingarbe (France) and may be used for applications in all market sectors. Vynova partnered with sustainability consultancy group Meo Carbon Solutions and selected the ISCC PLUS framework[32] to certify the bio-attributed PVC grades according to a mass balance approach (see Mass Balance concept).

Both INOVYN and VYNOVA claim that their bio-attributed PVC reduces CO_2 emissions by more than 90% compared to conventionally produced PVC, with no loss of properties.

4.1.3 The specific case of chlorine

PVC is a thermoplastic made of 57% chlorine (derived from salt) and 43% carbon (derived predominantly from oil / gas via ethylene). It is consequently less dependent than other polymers on crude oil or natural gas, and hence different from PE, PP, PET and PS, which are entirely dependent on oil or gas. With salt being its primary raw material, PVC uses comparatively fewer non-renewable fossil fuels in its production, which is both an environmental and economic advantage.

A renewable resource is any natural resource that replaces itself given enough time. The rate of replenishment must be equal to or faster than the rate of usage. Hence salt is not strictly speaking a renewable material. Nevertheless, salt is one of Earth's most abundant minerals, and there is little danger of supply ever running out. Salt is coming from mines or from sea water. 150 m is the thickness of salt which would be spread over entire Earth surface, if oceans were evaporated.[33] And this does not include salt mines.

4.2 Production of PVC additives

PVC products are made of PVC resin and additives (stabilisers, plasticisers, pigments, impact modifiers, fillers, etc.). Resin, plasticisers and fillers together represent more than 90-95% of the weight of the final product.
Approximately 80% of all the filler used in PVC is calcium carbonate. Titanium dioxide is second (it plays also the role of white pigment and UV stabiliser) at around 12%, followed by calcined clay at about 5%. The remaining few percent is taken up by other materials, which are not organic and hence fillers are not relevant with respect of moving to renewable sources.

The analysis and the comments below are consequently only related to the potential move to renewables of plasticisers and stabilisers. A comprehensive review of bio-based Additives for thermoplastics includes various kinds of PVC additives.[34]

4.2.1 Production of bio-based plasticisers

Plasticisers can represent up to 50% of the final PVC product weight, hence it is important to address plasticisers when investigating the potential of moving to renewables. The annual plasticisers consumption at global level is around 6 million tons, and around 1 million ton in Europe, the majority being used in PVC products. General purpose phthalates represent the bulk of the global plasticiser consumption. DEHP (di-2-ethylhexyl phthalate) has been substituted in Europe to a large extent by higher molecular weight phthalates such as DINP (di-isononylphthalate) and DIDP (di-isodecylphthalate). DINP and DIDP belong to the category of high molecular weight orthophthalates, which in 2017 accounted for about 55% of the European plasticiser market. Phthalates are manufactured from fossil fuels, which raises concerns in terms of carbon footprint and long-term sustainability. Some alternative plasticisers, such as terephthalates and adipates, are also produced from fossil sources.

Bio-based plasticisers have grown in importance in the past few years as a result of increasing challenges due to climate change and sustainability issues, as well as concerns about the hazards of some phthalates. Their toxicological properties must however be assessed in the same way as for conventional plasticisers. The most usual raw materials for these bio-based plasticisers are the oils extracted from castor plant, soybean, palm, rapeseed, sunflower, linseed but also from starch (from corn, potatoes and wheat).

Replacing a general-purpose plasticiser, however, is not an easy task. Price and availability, performance (process ability, long-term compatibility and others) and toxicology have to be taken into consideration. Also, in the case of bio-based materials, factors like land use, water consumption and competition with food are to be taken into account.

Several bio-based plasticisers are already commercialised. Their performances are similar to the ones of traditional plasticisers. A few examples are listed below without any particular value recommendation:

- V-ZICLUM GP from Varteco Quimica Puntana S.A. (Argentina) is a 100 % bio-based general-purpose plasticiser whose main component is epoxidized soybean oil.[35]
- Polysorb® from Roquette Group, France, is a 100% biobased composition of isosorbide diesters coming from starch and vegetal oils.[36]
- GRINSTED Soft-N-Safe® from Danisco is an acetylated monoglyceride derived from hydrogenated castor oil.[37] Its environmental impact has been assessed by means of LCA.[38]
- Nexoleum, Brazil, has a range of chemically modified fatty acid esters sourced from carefully selected vegetable oils.[39]
- Resypar, Brazil, sells a range of plasticisers derived from vegetable oils.[40] Its product slate includes RESYFLEX® KX, RESYFLEX K 10, CELUFLEX AT 100 and CELUPLAST LM.
- Proviron, a Belgian company, markets a range of bio-based PVC plasticisers, e.g., Proviplast® 2624, an acetylated tri-butylcitrate (ATBC), Proviplast 2755, 2705, 1944.[41]
- Perstorp, a Swedish company with production facilities in Asia, Europe and North America offers Pevalen™ Pro high-performance PETV (pentaerythritol tetravalerate) plasticiser made from partly renewable raw materials 'sourced in a responsible way'.[42] The concept behind Pevalen™ Pro is based on the mass balance approach.[43]
- Plant-based specialities Roquette manufactures bio-based building blocks for plasticisers. Its Polysorn isosorbide can be used to produce diester plasticisers.[44]

4.2.2 Production of bio-based stabilisers

The main stabilisers are metal compounds, anionic parts of which are often organic (e.g., stearate). Sometimes co-stabilisers (organic materials such as polyols or epoxidised esters) or even organic tin stabilisers are used. These substances may be partly or entirely obtained from renewable sources, e.g., sunflower oil.

Stabilisers however represent only a small part of the weight of final PVC products, and hence, as part of the potential move to renewables, the focus has to be put on PVC resin and plasticisers, rather than on stabilisers.

4.3 Production of other plastics

4.3.1 Overview

The Nova-Institute of Germany (**http://nova-institute.eu/**) is a private and independent research institute, founded in 1994, which offers research and consultancy with a focus on the transition of the chemical and material industry to renewable carbon. It published in 2013 a comprehensive market study of bio-based polymers.[45] It was the first time that a study had investigated every kind of bio-based polymer produced by 246 companies at 366 locations around the world and it examined in detail 114 companies in 135 locations. Considerably higher production capacity was found than in previous studies.

The Nova Institute regularly publishes research papers, some of which freely downloadable from the web page **http://bio-based.eu/nova-papers.** Some recent ones are:

- **'Global bioeconomy in the conflict between biomass supply and demand'**.[46] It presents the most important results of the study '*Sustainable biomass potentials for biofuels in competition to food, feed, bioenergy and industrial material use in Germany, Europe and the world*'. The results provide a view of possible scenarios for a sustainable supply of biomass until the year 2050, and of the development of demand in all biomass sectors. The stated outlook is *"the biomass supply, or rather the supply of renewable carbon, can be expanded much further by exploiting the described new technologies and system optimisations which allow a higher output with less input, and at the same time reduced environmental burdens. Hence, shortages by 2050 could be largely ruled out"*.
- **'The 'Circular Bioeconomy' – Concepts, Opportunities and Limitations'**[47] paper "*aims at highlighting the most important aspects related to bioeconomy and circular economy, clarifying some common misconceptions and addressing limitations we need to consider on our way to a "Circular Bioeconomy*". The bioeconomy and circular economy share some targets, i.e., "*a more sustainable and resource efficient world with a low carbon footprint. Both the circular economy and the bioeconomy avoid using additional fossil carbon to contribute to climate targets.*" However, "*despite the similarities and overlaps, bioeconomy and circular economy differ in a variety of aspects.*" It summarises by stating "*the concepts of bioeconomy and circular economy have similar targets and they are overlapping to*

a degree, but neither is fully part of the other nor embedded in the other." They can contribute in several ways to each other, including the utilisation of waste streams from various renewable sources to applications such as aquaculture feed and all kinds of chemicals and materials and "*linking different industrial sectors (food industries & chemical industry)".*

- **'Renewable Carbon is Key to a Sustainable and Future-Oriented Chemical Industry'.**[48] This paper stresses that "*The chemical industry may only develop into a sustainable sector once it bids farewell to fossil raw materials (…) and uses nothing but renewable carbon as a raw material in organic chemistry. However, it is not a decarbonisation, like it is quite reasonably called for in the energy sector, that will help this industry. After all, organic chemistry cannot be decarbonised, as it is entirely based on the use of carbon. This also includes the plastics industry – the modern world is inconceivable without its versatile polymers unless you are prepared to accept considerable sacrifices or higher greenhouse gas emissions. The equivalent to decarbonisation in the energy sector is a transition to carbon from renewable sources in the chemical and plastics industries.*" It reminds that "*There are only three sources of renewable carbon:*

  - *Renewable carbon from recycling of already existing plastics and other organic chemistry products (mechanical and chemical recycling).*
  - *Renewable carbon gained from all types of biomass.*
  - *Renewable carbon from direct CO_2 utilisation of fossil point sources (while they still exist) as well as from permanently biogenous point sources and direct air capture."*

The paper further states: "*How much of the chemical industry's raw material demand can be covered by biomass until 2050? Experts suggest that the 14 per cent share seen in 2015 may double or even triple by 2050*."

An Nova Institute article published in April 2020, titled "How much biomass do bio-based plastics need"[49] mentions that "*the 0.034% share of biomass used (in 2018 and 2019) to produce bio-based polymers which currently account for about 1% of the total polymer market translates into an area share of only 0.004%*." It concludes that "*Currently, the land and biomass required for bio-based polymers do not play a relevant role compared to other sectors and do not represent any relevant competition to other uses, in particular the food and feed sector. If 100% of the polymer demand were to be covered by biomass, the situation would be different. However, this scenario is highly unlikely, because new sources of renewable carbon will increasingly be used in the future, such as recycling, organic waste streams and the direct use of CO_2".*

A September 2020 article in a trade journal[50] predicts further growth and mentions a few recent developments, but none related to PVC. It reports that the European Bioplastics trade association predicted in December 2019 that global bioplastic production would increase from around 2.1 million tonnes in 2019 to 2.4 million tonnes in 2024. The article also mentions that *"packaging remains the largest field of application for bioplastics with almost 53% of the total bioplastic market in 2019."*

4.3.2 Specific examples

It is not possible to provide an exhaustive view of all initiatives to produce various polymers based on renewable resources within the scope of this document. An article from December 2014 published in a trade journal mentions a few.[51] It describes the progress made by company Braskem in the production of sugar cane-based polyethylene (see further down) with a cautionary warning: *"The environmental gains, however, come at a price and that, together with the slowdown in the most environmentally-aware market of Europe, has held back take-up*". *"Current technology for production of Green PE is more costly,"* Elias (N.B: Braskem director of renewable chemicals) *explained to AMI Magazines in a recent interview.* ***"It has to be a premium product, or it will not make any sense."***

The article further stressed that ***"growing development of Green PE is likely to be further impacted by the availability of potentially lower cost PE from the new generation of shale-fed polymerisation plants being constructed in the US."***

The article goes on by describing technical progress by companies TOTAL (Atol technology producing bio-ethylene by dehydration of bioethanol, using a high-performance catalyst) and BP, which started up in 2013 a fully integrated pilot plant at Hull in the UK to demonstrate its Hummingbird ethanol to ethylene dehydration technology. It reported also that company SABIC was taking a different approach with the introduction of its renewable PE and PP products by using renewable feedstock at the cracking stage in its Geleen plant in the Netherlands. The renewable content in the final polymer is certified under the International Sustainability and Carbon Certification (ISCC) framework, which involves a regime of traceability and calculation of '**mass balance**'.

4. ACTUAL CASES AND FURTHER OPPORTUNITIES OF SWITCHING TO RENEWABLE RAW MATERIALS FOR PVC

BASF was reported to use a similar approach. The article reports also initiatives to replace some of the key building blocks of the polymer industry with products from renewable or bio-based sources, and initiatives to produce bio-based alternative to PET and 100% bio-based nylon 6,6 as well as renewable polyamide. Finally, it mentions the opening of the first of the Matrica plants at the Porto Torres site in Italy established as a joint venture between chemicals company Versalis and bioplastics firm Novamont. The Matrica project was initiated with the aim of creating an integrated green chemistry facility exploiting vegetable-based raw materials. The first plant converted vegetable oils to monomers and intermediates; two additional plants were planned to enable production of extender oils for the rubber industry, bio-lubricants and polymer plasticisers.

The relatively positive conclusions of the 2020 Nova Institute article should nevertheless not obscure the difficulties to move to renewables. As an example, Braskem operates a 'green' PE plant in Triunfo in Southern Brazil which began production in 2010. This marked the beginning of Green PE production on a commercial scale. The plant ran however for several years far below its full capacity.

In February 2013, Braskem CEO said it did not plan to invest in 2013 in new plants that use ethanol from sugarcane to produce PP or PE, but bio-based plastic production remains clearly a key part of the company's strategy. Its green ethylene plant commissioned in September 2010 marked the beginning of I'm green™ polyethylene production on a commercial scale, securing the company's global leadership position in bioplastics. The plant has an annual production capacity of 200,000 tonnes of I'm green™ Polyethylene, which is produced from sugar cane. I'm green™ Polyethylene retains the same properties, performance and application versatility as polyethylene from fossil origin – which facilitates immediate use in the plastics production chain. For the same reason, it also can be recycled within the same chain of recycling traditional polyethylene.[52] Braskem also produces EVA (ethylene vinyl acetate copolymer) with raw material from a renewable source (sugar cane).

The I'm green™ stamp was created by Braskem so that the consumer recognises products made with renewable resin. To achieve this differentiation, the products have to pass a carbon 14 dating test, the same as done to find out the age of fossil materials found around the world. The condition to use the seal is that the product must contain at least 51% renewable material.

On the other hand, Dow Chemical and Mitsui delayed their project to produce PE from sugarcane in Brazil. In the project, ethanol would be used to produce 350,000 t/y of various grades of PE. The project would have been the world's largest biopolymers investment.

It is clear that for all companies the economics of bioplastics production has come into question because of the availability of cheap shale gas feedstock in the US. Developments are therefore happening more in the field of speciality chemicals and plastics. It may be worthwhile mentioning, as examples among others, two companies which are very active in this field:

- The Roquette Group (**https://www.roquette.com/**) *"offers the industrial markets new, innovative and sustainable monomers". "Roquette has developed a high purity, versatile ingredient with outstanding qualities and functionalities: POLYSORB.® This enables polymers to be more resistant to temperature and have better mechanical and optical properties. POLYSORB® can be used either directly as a very pure monomer or in the form of a derivative (functionalized monomer or plasticizer). It offers valuable solutions to performance materials markets: polyesters, polycarbonates, composites and coatings, polyurethanes, TPU, etc.".* Roquette also markets BIOSUCCINIUM® which it claims offers a renewable alternative to succinic acid, a chemical traditionally used directly in a variety of industry applications for the production of several polymers and resins. It claims that *"BIOSUCCIUNIUM® opens up many possibilities to create high-performing and sustainable end-products: from packaging and disposable plastic-based products to composites and coating, going through anti-corrosion and cooling fluids".*[53]

- Novamont is an Italian company claiming to be *"international leader in the bioplastics sector and in the development of biochemicals"*.[54] It markets among other products its MATER-BI *"innovative family of biodegradable and compostable bioplastics, (…) obtained by means of pioneering proprietary technologies using starches, cellulose, vegetable oils and their combinations (…) used in a wide variety of sectors"* (agriculture, carrier bags, single-use food and drink consumption utensils.[55]

Last but not least, a dedicated page on PlasticsEurope's Website provides access to relevant information.[56]

5. FURTHER CONSIDERATIONS ABOUT SWITCHING TO RENEWABLE RAW MATERIALS IN THE PVC INDUSTRY

5.1 Methodology to track and assess the contribution of renewable raw materials – Mass Balance concept

Mass balance is one of the Chain of Custody models as described by the ISO 22095 standard which can be used to trace the flow of materials through the value chain resulting in associated claims. Other models described by this standard are: Identity preserved, Segregation, Controlled blending, Book and claim with certificate trading within open markets. These different Chains of Custody models vary in terms of detailed knowledge of the source of the product, the complexity of implementation and the recycled content in the end-product which will in turn affect the related claims.

As renewable feedstock may be processed together with non-renewable feedstock, it might not be physically traceable via carbon-14 dating throughout the production processes. Therefore, there is a need to attribute the renewable feedstock to an end-product in a fully transparent and auditable way. This approach can be seen as complementary to other efforts in the production of bio-based chemicals/plastics. It allows a drop-in solution in existing chemical installations and logistics. In this case, the mass balance Chain of Custody approach is applied. The actual carbon molecules in the chosen chemical/plastic may not be bio-based, but through a third-party certificate, the use of the renewable feedstock and the corresponding attribution to certain amounts of chemicals/plastics can be verified.

The mass balance approach can either be based on physical connections or on transfer of product characteristics without physical connection. This latter transfer of product characteristics can be an option when renewable feedstock availability or quality at the entry point would be inadequate and/or complicated company internal material supply chain logistics can be avoided. Similar logistic considerations hold for the availability and efficient use of process units and supply chains that convert renewable (attributed) intermediates into products reducing transport and hence enhancing supply chains. The condition for such transfer of product characteristics is that the transfer takes place between sites producing the same substance under special contractual agreements.

Companies applying the mass balance approach production processes should ensure the following key criteria are met and auditable by an independent third party thus guaranteeing credibility of the claim.

- **Feedstock qualification:** A clear description of the qualification of the responsibly sourced renewable feedstock and how it contributes to a measurable greenhouse gas saving compared to its fossil counterpart.

- **Chain of Custody:** Clearly defined system boundaries and scope to the chain of custody. Material flow along the Chain of Custody and bill of materials must be third party auditable. Each Chain of Custody approach must require a publicly available standard.

- **Product claims:** Verifiable and certified product claims. These products are Renewable Attributed Products and must not be called "bio-based products"

More information can be found in the view paper published by PlasticsEurope in 2020.[57]

5.2 Technical aspects and availability of renewable resources

Ethanol has been produced by the fermentation of carbohydrates for thousands of years. In the late 1930's, due to low oil prices, ethanol was also industrially obtained through direct and indirect hydration of petroleum-derived ethylene.

The rising crude oil price and drive to sustainability later motivated researches on ethanol from biomass sources. Ethanol from biomass can be produced by the fermentation of starch (from corn), sugar (from sugarcane) or waste lignocellulosic biomass (such as corn stover or switch grass), and even of algae. After adsorption/distillation steps, dehydration, an endothermic equilibrium reaction is carried out in the presence of a catalyst to produce ethylene. There are different processes linked to different patents, but all are based on the same principle: fermentation and dehydration.

Ethylene produced in this way does not chemically differ from ethylene produced by steam cracking of oil or gas fractions. Hence there is no technical obstacle to the production of bio-based PVC. Three generations of bioethanol production processes can be listed:

5.2.1 1st generation – grain and sugar-based ethanol

The processes of milling (cutting of cane into regular pieces) and raw sugar refining are usually done together on one site. During milling the sugar cane is washed, chopped and shredded by revolving knives. The shredded cane (20-25cm) is fed into mill combinations which crush and extract the cane juice. The juice is filtered and pasteurised (treatment of heat to kill micro-bacterial impurities) along with chemicals. Bagasse, the waste matter from the cane sugar is used as a fuel for the bioethanol plant boilers and it can produce heat and steam on a self-sufficient basis. The cane juice is filtered to remove 'vinasse' – the unwanted non-alcoholic black-red liquid. Vinasse has been considered an annoying waste product and a burden and environmental hazard due to its viscous nature and high acid content. Some uses include combustion and use as potassium fertilisers. After the vinasse is removed the syrup is then put through evaporation and cooling crystallisation. It leaves clear crystals and molasses.

The molasses are separated from the crystals by centrifugation. Further pasteurisation and fermentation processes take place before distillation to a higher concentration of alcohol.

In Brazil, 1-ha land yielded on average 72.5 tons of sugarcane between 2016 and 2019, which gives 6,200 l ethanol from which 2.6 tons of ethylene can be produced. Ethanol is widely used as fuel in Brazil and in the United States, and together both countries are responsible for the largest share of the world's ethanol fuel production.

5.2.2 2nd generation – lignocellulosic material to ethanol

The second generation of bioethanol production holds the potential benefit of achieving better carbon savings per hectare of land than the first generation and a wider range of lower cost feedstocks including straw, waste paper and waste wood. These benefits will require substantially higher plant capital and operating costs, and until these technologies have been tried and tested there will be a significant level of technology risk.

The second-generation production methods that can convert ligno-cellulosic (woody) plant matter into ethanol would allow more biomass to be converted to ethanol, either by using the whole of conventional crops or faster growing crops such as switchgrass.

The key technical problem is how to break down the resilient lingo-cellulosic carbon chains into molecules that can be converted to ethanol or other liquid fuels such as methanol or butanol.

However, despite these concerns, several industrial installations have been built in recent years. For example, INEOS Bio completed in 2012 the construction of the world's first commercial scale bioethanol production at Vero Beach, Florida using new advanced bioenergy technology to convert waste to renewable fuel and electricity. The technology was based on a combination of gasification and fermentation technology for the conversion of biomass waste into bioethanol and renewable power. The renewable resources were sourced from vegetative and wood waste.

However, despite investing three years and untold millions INEOS Bio ultimately failed in its attempts at using a gasification fermentation to convert yard and vegetative waste into ethanol. The plant ran into trouble months after construction was completed because unforeseen levels of hydrogen cyanide, which is toxic to the bio-organisms in the fermentation process.

Expensive wet scrubbers were installed in late 2014 to remove the hydrogen cyanide, but less than two years later, INEOS said the market for ethanol had changed and it would sell its ethanol business, including the Vero Beach demonstration plant. Texas-based Frankens Energy and its partners bought the site in January 2018 with a different plan for its use. Earlier in 2019, the group auctioned off surplus equipment from the failed ethanol plant.[58]

Another example of development is the involvement of INEOS in the *Hållbar Kemi 2030* project. INEOS Sverige AB is one of seven key chemical companies forming a chemical cluster in the Stenungsund region of Sweden. Through this cluster a unique partnership has emerged, creating a vision known as Sustainable Chemistry 2030 *(Hållbar Kemi 2030)*.

The common vision is to ensure that by the year 2030, Stenungsund will be the hub for the manufacture of sustainable products within the chemical industry. Its vision is that operations will be based on renewable feedstocks and energy which will contribute to a sustainable society. In particular, various feedstocks will be evaluated for potential sources of ethylene derived from renewable sources. Importantly, one of the key sources of renewable feedstocks is available from the forestry industry which has an abundance of natural resources. Bringing industries together that, to date, have had no common interest, is one of the unique aspects of Hållbar *Kemi 2030*. See for example a press release of 2020[59] and web page.[60]

In Italy, the Crescentino's Biorefinery opening was celebrated in October 2013. Operating at full capacity, the bio-refinery constructed by Beta Renewables (Mossi Ghisolfi Group) was designed to produce second-generation bioethanol from non-food biomass such as lignocellulose from agricultural residues. The project was supported by the European Commission within the 7th Framework Programme for Research and Technological Development.

The plant in Crescentino has a capacity of 40 kt of bioethanol per year, starting from over 200,000 tons of biomass (dry mass), such as wheat straw. The site includes a boiler for electricity from lignine (13 MW capacity), a dedicated wastewater facility with full water recirculation, including production of biogas. The plant represents an investment of 150 million Euro.[61]

5.2.3 3rd generation: biowaste and algae – based ethanol

The abstract of an academic review article published in 2016 states: *"There are three routes for producing bioethanol from microalgae and cyanobacteria: the traditional one involving hydrolysis and fermentation of biomass with bacteria or yeast, the dark fermentation route, and the use of engineered cyanobacteria or 'photo fermentation'. In recent years, the use of engineered cyanobacteria to directly produce ethanol has gained enormous attention, mainly after the successful use of these microorganisms in industrial plants. However, only little information is available on the efficiency and the real advantages and disadvantages of these processes, and particularly, a comparison between traditional processes and engineered cyanobacteria. This study compiles the main publications on the production of bioethanol from microalgae and cyanobacteria, and summarizes the main features, advantages, and key aspects for each type of process".*[62]

Another academic article from 2019 focuses on the fermentation of pre-treated microalgae biomass, which the authors claim is the option receiving currently the most attention. It describes the latest advances in enhanced carbohydrate accumulation, biomass pre-treatment, starch and glycogen downstream processing and various fermentation approaches.[63]

There are not many examples of industrial implementation. A process to produce bio-ethanol from algae is however being developed by the company Algenol.[64] Headquartered in **Fort Myers, Florida**, Algenol is an industrial biotechnology company that is commercializing patented algae technology for production of ethanol and other fuels. Algenol's technology potentially allows production of ethanol, gasoline, jet, and diesel fuel, but to date has not been successfully implemented in commercial production. The technology relies on patented photobioreactors and proprietary downstream techniques for low-cost fuel production. These low-cost techniques consume carbon dioxide from industrial sources, do not use farmland or food crops, and provide fresh water. Their biofuel technology uses sunlight, algae, non-arable land and carbon dioxide to produce ethanol and the leftover spent algae that can be converted into other biofuels. The technology uses blue-green algae (or cyanobacteria) to change CO_2 and seawater into sugars and then into ethanol and biomass.[65]

5.2.4 Perspectives

The feasibility of the first-generation processes, based on grain and sugar has been technically demonstrated, and plants have already worked on an industrial scale.

The feasibility of the second-generation processes based on lignocellulosic materials has been demonstrated at pilot plant level. The functioning at industrial scale has still to be optimised and confirmed, depending very much on the quality of the raw material.

However, both first and second generation are presenting characteristics which do not necessarily make them attractive for investors, certainly not at the present time:

- their competitiveness compared to traditional processes based on oil or gas is very much depending on oil and gas prices.
- their competitiveness is also very much depending on the localisation of the fields/ forests, and the localisation of the ethanol production factories, both adding transport costs.
- sugar cane and suitable forests can only grow in certain regions, and there is not

enough suitable land available in these regions to supply the whole world with ethanol.

- except in some specific cases where sustainability claims can provide a commercial advantage, most customers are not prepared so far to pay a premium to buy bio-based products.

- the environmental footprint of these two generation processes is not evidently better than the ones of traditional production processes, and comparatively recognised and accepted assessment methodologies are still under development, as outlined in the **Environmental impact section** of this report.

The third generation appears in principle more promising, as algae production can be made without significant land use, and most probably without a significant impact on the environment. However, this approach still requires much research and development work.

5.3 Environmental impact

A chapter of an academic book published in 2016 provides a holistic view of the sustainability and lifecycle aspects of bio-based PVC.[66] It reviews the sustainability aspects of PVC produced from bio-sourced ethylene, notably ethylene from bioethanol. It describes a LCA comparison of PVC produced from sugar cane-based bioethanol with fossil-based PVC. The comparison showed that *"the bioethanol-based PVC has better results than the fossil-based PVC solely in the categories of non-renewable resources and climate change"*. In 12 other environmental impact categories the fossil-based PVC had better environmental performance, due to the impacts of sugarcane cultivation and harvesting (land use, use of fertilisers and pesticides). In order to compare the overall performance, the authors performed the optional LCIA stages of normalisation, aggregation and weighting. It appeared that *"although the bioethanol-based PVC had better performance only in 2 categories on a total of 14, the extent of those benefits was much higher than the damage from the other 12 categories."* This conclusion was however only deemed, valid if the land dedicated to the additional sugar cane cultivation is not obtained by deforestation in the Amazon Forest.

In 2018, the GROW Directorate of the European Commission entrusted its Joint Research Centre (JRC) with the project 'Environmental sustainability assessment comparing through the means of life cycle assessment the potential environmental impacts of the use of alternative feedstocks (biomass, recycled plastics, CO_2) for plastic articles in comparison to oil and gas'.[67]

The main purpose of this project is to:

- *"Elaborate a consistent and appropriate LCA-based method to compare the potential environmental impacts of the use of alternative feedstock sources for plastic article production, taking also into account differences in biodegradability properties of the materials obtained from such feedstock, and*

- *Demonstrate the applicability of the developed methodological framework to a number of detailed LCA case studies for ten (10) selected plastic articles."*

A draft report for public consultation was published in 2020. This report addresses the outcome of the systematic review of selected relevant studies and the refined method for comparative LCA of the use alternative feedstock sources for plastic articles production. The method presented in this report builds upon the general structure, requirements and recommendations of the latest suggestions for updating the Product Environmental Footprint (PEF) method.

Ten case studies are reviewed in a separate document also published by the JRC in 2020. Three cases are relevant for water and food packaging (beverage bottles, flexible food packaging film, trays for food). Other cases include agriculture mulching film, nursery pots, automotive interior panels, printer housing panels, monobloc stacking chairs and wipes. One case only is relevant for Building and Construction, namely insulation boards. PVC is hardly mentioned in this review.

It is important to mention also that *"plastics made from bio-based materials are not necessarily compostable or biodegradable. Moreover, plastics that do biodegrade can be made from fossil fuel-based materials"*.[68]

5.4 Economic aspects

The key factor is the production cost of ethylene coming from bio-based raw material compared with the market price of ethylene produced from oil or gas. This comparison must be made on a case-by-case basis, and the results vary significantly over time. The production cost of ethylene coming from bio-based raw materials is directly depending on local (e.g., labour costs) and cyclical conditions. As an example, when ethylene is coming from sugar cane via ethanol, its cost is directly linked to the global sugar market price, which can be very volatile. Likewise, the price of ethylene produced by steam cracking oil or gas products depends very much on the price of crude oil and gas, both also rather volatile. It is therefore impossible to draw a general conclusion.

The fact is that over the last decades, only a limited number of companies have been interested to invest in ethylene from ethanol, and that some who had decided to initiate such investments later put such initiatives on hold, even at moments when the price of oil was around USD 100 / barrel. **The current market conditions still do not ensure an economic incentive for a significant switch to renewable carbon sources within the petrochemical industry in general, and PVC production in particular.** The recent collapse in oil prices due to the Covid-19 pandemic reduces even further the economic incentive for switching to renewable raw materials.

5.5 Other aspects

The issue of climate change has gained enormous importance in the few years since the December 2015 agreement at the Paris COP 21 meeting. This is driving massive investments in renewable energy sources and numerous commitments by public entities as well as companies to achieve carbon neutrality within the next few decades. Bio-based feedstocks may contribute to such objectives, but they must be carefully evaluated from a carbon-neutrality perspective and are not currently the main pathway chosen by investors.

Investments in bio-based products are still driven by other factors than economics, namely:

- Public policies, e.g., via financial incentives or mandated targets.
- Requirements by customers further down in the value chain for products based on renewable resources to supply niche markets where such characteristics provide a distinct advantage.

5.6 Summary of opportunities and obstacles

A switch to renewable raw materials still faces two major obstacles, at least in Europe:

- Lack of economic incentives, especially when oil prices are low.
- Availability of bio-based ethylene.

Concerns about fossil sources of carbon possibly running out in the near future have also somewhat receded in recent years, thereby lessening the urgency of finding renewable sources of organic materials.

On the positive side, there are no major technical obstacles to such a switch. Polymers produced from renewable raw materials can be technically identical to traditional polymers. Some customers are prepared to accept and pay a premium, or even request such polymers, because they can include this premium in their own sales prices. This is the case for producers of luxury applications (e.g., luxury 'leather' goods), and more generally of producers seeing marketing benefits from using 'green' polymers. Hence the products the most likely to be made of green polymers in the near future are definitely niche products.

In addition to reduction of CO_2 emissions and benefits in terms of sustainability in general and image, renewable resources are considered beneficial for valorisation of agricultural wastes and jobs creation.

Their overall environmental impact must be assessed on a case-by-case basis and its assessment is still hampered by the lack of generally accepted methodology, in particular to take into account availability of land (competition with traditional agriculture), and potential deforestation.

6. OTHER WAYS TO REDUCE THE USE OF NON-RENEWABLE RESOURCES

6.1 Durability, re-use and recycling

With regard to the depletion of the non-renewable raw materials reserves, producing more durable products and/or products that can be reused achieves the same objectives as switching to renewables, and even save raw materials in general.

Recycling also helps to save raw materials and reduces energy consumption and CO_2 emissions compared to the manufacturing of virgin products. A study by PE International in September 200[69] concluded: *"GWP (Global Warming Potential) of the incineration process is substantially higher than that of the mechanical recycling in all modelled scenarios. As the recycling process recovers more of the material, more production steps are substituted and therefore, the GWP is lower for this recycling route. The additionally incurred greenhouse gas production is ca. 3 kg in case of cable incineration, and ca. 4.4 kg in case of rigid profile incineration. Even when considering the worst-case scenarios of both mechanical recycling routes, the greenhouse gas emissions are at least 2.3 kg and 3.5 kg higher, for cable and rigid profile incineration, respectively."*

Such estimations depend of course on the assumptions and assessment methodology. Alternative assessments yield somewhat lower GWP reduction figures. VinylPlus therefore claims a more conservative figure of 2 tons of CO_2 emissions avoided per ton of recycled PVC.[70] Recycling is a key component of waste reduction and is the third component of the 'Reduce, Reuse and Recycle' waste hierarchy.

PVC is well positioned regarding recycling, as PVC can be recycled several times without degradation of its mechanical properties, which is a serious advantage compared to many other polymers.

The European PVC industry, through VinylPlus, supports the development of recycling, in parallel to making progress on the transition to renewables.

6.2 Including renewable raw materials into PVC products

Several plastics converters have developed Wood-Plastic Composites (WPC) over the last decades, in particular for outdoor applications. Decking is the dominant one, but several other applications are under development: roofline products, cladding/siding, window profiles, fencing, rails, sound insulation, …WPC help reduce non-renewable raw materials consumption related to virgin plastic production by replacing a significant part of plastic by wood powder and even wood waste.

One might argue that in such applications WPC may be replacing wood which is already per se a renewable material, but the point is that wood used for these applications is high quality one, often exotic and not always coming from renewable forests, and that wood used as part of WPC is wood powder often coming from wood waste. Up to 60% wood (certified PEFC - Programme for the Endorsement of Forest Certification or FSC - Forest Stewardship Council ensuring responsible management of forests worldwide, including social aspects like child labour and corruption) can be incorporated, with the result that, taking into account the chlorine content of PVC such composite PVC products consumes four times less non-renewable raw material than an alternative plastic product made of 100% crude oil-based material.

In addition, replacing wood by WPC dramatically increases the durability of the products, which is another significant added value as part of progress towards sustainability.

An alternative to WPC but with the same benefits as mentioned above is Resysta,® made from approximately 60% of rice husk, a food industry waste product, and 40% PVC.[71] By a variety of different manufacturing processes, products are created that are claimed to exceed wood or WPC quality. Products made of Resysta are weather-proof, water-resistant, and UV-resistant, with minimum maintenance requirements. The products look and feel like wood; the material does not splinter or rot over time. The products are also 100% recyclable. Resysta products include decking, parquet, façades cladding, window frames, furniture, fences, etc.

7. CONCLUSIONS

PVC products are made of PVC resin and additives. Regarding the move to renewables, the focus should be on PVC resin and plasticisers, which are by far the largest contributors to the carbon content of PVC products. The chlorine content of PVC resin is 57%. Its source (common salt), although not renewable in the strict sense, is almost inexhaustible, which limits the fraction to be potentially sourced from renewable raw materials.

The share of plastics in general, and PVC specifically, produced from renewable raw materials remains low. There are no technical barriers to the production of plastics from renewable raw materials. The processes to produce ethanol from some crops have been known and widely used for centuries. Producing ethylene from ethanol is also a well-known process and ethylene obtained in this way is chemically identical to ethylene produced from oil or gas, hence can be used in the same industrial installations without any modification.

The barriers are essentially related to economics and to the limited availability of bio-sourced petrochemicals, both somewhat linked by competition with food and feed crops on the one hand, heightened by concerns about deforestation, and the availability of still cheap oil and gas on the other hand. Competition with food and feed could be lessened by processes using biological material either discarded from food/feed crops or grown in a way which does not compete with such crops (e.g., algae). A lowering of the economic barrier had been expected due to the steady cost increase for oil and gas which was foreseen at the beginning of the present century. This has not happened, partly due to the rise of shale gas and partly because the development of renewable energy has lessened demand growth of oil and gas to produce energy. This is a consequence of the increasing importance of climate change, which pushed concerns about availability of oil and gas to the background. Replacing non-renewable carbon in plastics is potentially less economic and less eco-efficient than replacing non-renewable carbon in energy production by solar panels, windmills and other carbon-free technologies. As a result, concerns about oil and gas have actually moved from limited availability to low demand, i.e., from 'peak oil' to 'stranded assets'. The recent collapse in oil prices due to the COVID-19 pandemic reduces even further the economic incentive for switching to renewable raw materials in the short term.

The economic barriers remain high to such an extent that many companies which were committed to move to renewables have put their plans on hold, and that early attempts have been reversed in many cases. In view of the rather low current traditional raw material prices, it is clear that very few companies will move to renewables in the current circumstances.

There is some evidence that the use of biomass from plants helps to reduce CO_2 emissions due to capture by the plants, but the overall environmental assessment results very much depend on the impact of transport (location of the fields and of the facilities for ethanol and ethylene production), the impact on nature (potential deforestation, agricultural land use, biodiversity), and the location of the PVC resin production facilities. Regarding plasticisers, there are already many bio-based ones available on the market, supported by concerns about risks of some traditional plasticisers. Appropriate performance must still be ensured, and market prices of biobased plasticisers must be competitive.

Despite all the obstacles, VinylPlus shares the views of the industry associations and NGOs about the benefits of developing renewable raw materials, provided it achieves more sustainability. A globally agreed comparative sustainability assessment methodology should be developed, including all sustainability aspects (CO_2 emissions, other environmental impacts, agricultural land use, deforestation, transport, external costs, etc.).

In the present circumstances, overcoming the barriers would require political will at global level implemented in concrete and effective policies to:

- Support R&D to develop renewable resources which do not compete with food and feed and which can eventually achieve economic sustainability. R&D on renewables should in particular support the development of the **3rd generation** of ethanol production because it alleviates the land use issue.
- Internalise the costs of non-renewable raw material sources, based on an accepted methodology for comparative sustainability assessments.
- Implement rational incentives to purchase bio-based products (e.g., public procurement guidelines) when their sustainability advantages can be clearly demonstrated.

Competition being global, only globally significant policies would allow a rapid switch to renewable raw materials, but they would require global agreements which are still unlikely because of differences in the economic development and climatic conditions of the various regions of the globe. As a consequence, renewable raw materials will in the short term remain limited to niche markets, where the eco-friendly image of the products compensates higher prices.

Last but not least, the potential of recycling should not be underestimated as part of the debate on the use of renewables. With regard to the depletion of the non-renewable raw materials, recycling achieves the same objective as moving to renewables, and even saves renewable raw materials for other uses. In addition, recycling helps to reduce energy consumption, and reduces use of incineration and landfilling. Because of its recycling potential and its technical characteristics, PVC is well-positioned in this aspect. The social aspects of the potential move to renewables have not been covered in this report.

TNS BRIEFING NOTE ON RENEWABLES

Introduction

VinylPlus Challenge Four (Sustainable Energy & Climate Stability) states that we will help minimise climate impacts through reducing energy and raw material use, potentially endeavouring to switch to renewable sources and promoting sustainable innovation.

The publicly stated targets in this area (at the launch of VinylPlus) are as follows.

Establish Renewable Materials Task Force by end first Quarter 2012.

Renewable Materials Task Force's status report by end 2012.

Early in 2014 The Natural Step was asked to look at the work done to date to help identify how to make further progress. The review is based on a series of PowerPoint presentations containing data collected by Joachim Eckstein and a small TF group. The documents cover the following topics:

Energy efficiency

Resource optimization

Renewable resources

Bio-based

Bioplastics

TNS is specifically asked to:

Review what has been investigated

Identify the relevance in terms of the VP programme

Identify possibilities for progress

Look at information gaps and future steps.

REVIEW OF EXISTING DOCUMENTS

General comments

The research summarised to date shows that this is both an important emergent arena and a very complex one, with several areas of potential confusion.
It is also one which is changing constantly as the market finds its way forward. Some of the research quoted here is probably in need of updating (from 2010 and 2011).
The information is generally not well structured, and it is easy to get lost in the details.
It could be important to keep the distinction between feedstock replacement and additive replacement. The notes we have seen would be better used if organised along those lines.

Key themes and signals of change

While much of the documentation looked as specific technologies and policy developments we noted some key themes and signals of change that are worth highlighting:

Multiple signs of sustainability-driven markets – The documentation makes reference to a lot of different policy and business activities that should be seen as evidence that sustainability is driving the future markets in quite profound ways. Signals include: price increases, greater legislative demands, debate over response strategies, growing impetus for more ambitious targets, exploration of new technologies that address the identified problems (e.g., CO_2 emissions, energy efficiency, renewables, bio-based feedstocks).

Confusion over terms and debate on details – the documents highlight many different views on sustainability and debate over the merits of different technologies (e.g., is bio-based better for the climate?). What is lacking is the shared vision amongst all these actors on the ultimate requirements for sustainability. This in turn means that each technology is promoted as either a step away from a current problem or an improvement on the status quo rather than being seen in the context of a transition strategy toward a sustainable goal. This is important for VinylPlus because the programme already has a shared vision for PVC that is based on full alignment with the system conditions. This means that the technologies should be assessed with the end application and sustainable management regimes as the starting point – how will this particular technology help achieve our vision?

Precautionary principle is back in focus – We note that there have been recent attempts by industry to attack the precautionary principle. Our view is that when used in a back-casting perspective (i.e., there is agreement on the long-term need to align with the four system conditions), then the precautionary principle should serve as a guide to innovation, rather than a deterrent.

The social dimension is in greater focus with biosourcing – Social dimensions on sustainability become increasingly important when considering use of biological resources as feedstocks. In essence, material sourcing becomes a direct competitor to other societal land use needs and living organisms.

Emerging methods development and standardisation – there are improvements being made in approaches to Life cycle thinking, including quantification of methods for carbon footprinting. This is a positive development to be encouraged and monitored while always keeping sight of the long-term sustainability objectives.

Measuring the social benefit – The metrics above focus on measuring the size of the footprint and tend to give less attention to measuring the actual positive benefits from a material or product.

RELEVANCE OF INFORMATION TO VINYLPLUS CHALLENGES

1. The potential for renewables in relation to PVC covers very different aspects. There is probably no single renewable source to deal with so many possible applications even just with PVC. We see developments across all kinds of 'bio' material, and all have their own implications, including a variety of social and economic impacts.

2. In our view all options for using renewables with PVC need to be fully evaluated for their sustainable development potential and impacts. VinylPlus should continue its model of using TNS System Conditions to assess every proposal for renewable uses.

3. As substitutes for hydro-carbon feedstock much is already happening but at variable pace in different geographical contexts. And as substitutes for PVC additives there is also a lot already happening.

4. The innovations happening on renewables are very relevant to PVC. Much of the information covered in these notes is actually more relevant to other plastics rather than PVC, yet it is important to keep those under observation too as some innovations could impact the PVC market particularly if they change the characteristics of other plastics where PVC has a current application. Alternatively applying renewables for PVC could result in new market applications for PVC at the expense of other plastics.

5. It should be expected that if the world makes progress on climate change strategies, with 2015 being crunch-time in the view of most experts, then a more realistic price on carbon will stimulate the renewables market dramatically.

OPPORTUNITIES FOR VINYLPLUS

Additives Taskforce – The expansion of renewables as Additives for PVC is already on the agenda for VinylPlus and the work of the Additives Task Force is a readily available and easily communicated possibility already scheduled to happen in 2014. We recommend keeping that focus and keeping that work distinct from feedstock renewables.

Renewables as Feedstocks – It would be possible thus to give a fresh focus to renewable feedstock's and begin to think more about the potential here.

Controlled-Loop Taskforce – It would also make sense to ask the Controlled Loop Task Force to give attention to the recycling and reuse implication of more renewables being used as both feedstock and additives – what would that mean for recycling technologies and what might be the challenges (such as legacy issues?).

Explore the potential of the Circular Economy – this concept is getting a lot of attention and the VinylPlus commitments demonstrate a model for how PVC can be used in a circular economy. There is a good story to tell, showing that the programme is working right across the spectrum with renewable feedstocks and closed loop management being both particularly relevant here.

Climate-solving – Ideas such as sourcing carbon from biomass, or even directly from the atmosphere, combined with long product life and closed loop resource management could start to position the PVC industry as a net contributor to climate solutions. This is something to explore further.

Clarifying the issues – There is an opportunity to show leadership by clarifying the differences in terminology and demonstrating a nuanced approach. Something as simple as a a glossary of terms clarifying VinylPlus views could be considered.

Backcasting perspective – Related to the point above, VinylPlus should be promoting its vision and working toward the design of the most optimal material streams from a systems perspective. This will ensure that trade-offs are not debated in isolation from the longer-term objectives. In practice, this would mean more exploration of the function of PVC products in different end use applications and an explanation of what the best material management strategies are. The investigation of the technologies and sourcing possibilities then follow.

Safeguard social sustainability – as VinylPlus takes further steps with renewables, it will be important to demonstrate a responsible approach. The TNS system conditions cover the social dimension, and we think this could be taken up more by VinylPlus, especially giving the range of social issues associated with sourcing of renewables. We have also included some examples guiding principles that were developed when thinking about biotechnology in the next section.

Use the precautionary principle to drive rather than stifle innovation – as we have noted previously the precautionary principle should be seen as an aid to guide innovation toward VinylPlus objectives, not as an inhibitor. This line of thinking would be positively received by many stakeholders.

INFORMATION GAPS AND POSSIBLE ACTIONS

Here follows some reflections on what we see as gaps in the literature and possible areas for action.

There are several areas needing more attention – food vs fuel – durability vs compostability – energy implications – recycling & re-use implications – waste elimination – consumer advice – regulation – use of GMO technology in renewables, and more.

Clarifying the motivation for shifting to renewables – We think this should be explicitly stated by VinylPlus as it seems to be an area of debate and confusion in general. When talking of energy, currently the main driver of a shift from fossil to renewable sources is concern about climate change (but not solely). This is connected to the net introduction of CO_2 to the biosphere, which is systematically increasing in concentration in nature, leading to climate change. However, when it comes to feedstocks, if VinylPlus is striving for closed-loop management of PVC materials, then this implies that emissions would be captured, and material recycling achieved (i.e., no climate change contribution). This might be possible even with fossil hydrocarbon feedstocks, though there are many assumptions to explore with that approach. And there are remaining reasons for shifting to renewables – finite resource depletion, other environmental impacts, economics and geopolitical issues. We think it is important for VinylPlus to fully explore and communicate the rationale.

Emerging, non-conventional alternatives – It should also be borne in mind that research is moving quickly. There is a growing question about the possibility of converting existing oil-based technologies so as to remove or reduce the climate change problems. None look feasible at this stage nor economic. And climate change is not the only problem with oil. It is definitely not renewable in any human timeframe. Yet it is not impossible to imagine that some form of carbon capture and even reuse can be developed as a transition stage. Removing the carbon climate change impacts from coal, for example, is now getting some attention. It is possible that supply of hydro-carbon raw materials for the chemical industry could become de-coupled from the much larger transport and energy uses.

Chlorine chemistry – The big issue which is only touched upon in the notes is about the other main component of PVC – the chlorine. VinylPlus has made a start on tackling the problems associated with chlorine via the dioxin consultations. The target put forward by TNS also envisaged looking at the sustainability impacts of chlorine use. Can it ever be regarded as a sustainable? What are the challenges for the chlorine industry to overcome in that context? A study of that question should now go forward and be done as part of VinylPlus' work on renewable alternatives. We believe there are hazardous aspects of chlorine production and use which need more work. Without digging at that question whatever the PVC industry tries to achieve on sustainable development, including renewables, will be undermined in many quarters by the chlorine factor. And what is the effect of chlorine when combined with renewables?

Responsible biotechnology – the emergence of biofuels highlighted issues like food vs fuel and a shift into renewables as feedstocks will raise similar questions around trade-offs and unintended consequences. We have only recently seen evidence of well-thought-out plans for responsible biotechnology and would like to present the following guiding principles as an example of the types of considerations that should be made when moving into renewables:

1. Aim to achieve substantial societal and environmental benefits, as well as business benefits.
2. Support regulatory and governance structures that put public interest and private ain on equal footing and promote extensive stakeholder engagement.
3. Avoid adverse impacts on food security and affordability.
4. Secure demonstrable, substantial reductions in greenhouse gas emissions.
5. Commit to production systems that optimise conditions for biodiversity and healthy ecosystems.
6. Commit to manufacturing processes that maximise the value of all feedstocks (e.g., closed-loop systems).
7. Place no additional burdens on the availability of scarce water supplies.
8. Avoid any risk of gene transfer in the open environment.
9. Pose no threat to human health.
10. Achieve the highest standards of health and safety both for workers and surrounding communities.

Source: J.Porritt – Sustainable Returns: Industrial Biotechnology Done Well

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