Techno-economic Feasibility of Large-scale Production of Bio-based Polymers in Europe

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Executive summary

For several decades, plastics derived from fossil fuels have grown at a faster rate than any other group of bulk materials, and expectations are that this high growth trend will continue until 2020. This study analyses the question if bio-based plastics, being derived from renewable resources, could serve to offset to a certain extent the non-renewable energy use and greenhouse gas emissions of the EU plastics industry, as well as having other advantageous socio-economic effects such as diversifying agricultural land use.

An overview of the types of bio-based polymers, their producers (including their location), the production processes applied and the types of uses shows that bio-based polymers is an emerging field which is characterised by new synergies and collaborations between a broad variety of actors of the chemical, biotechnology, agriculture and consumer goods sector.

In order to obtain a better understanding of the importance of this emerging sector estimates have been made firstly for the technical substitution potential and then for more realistic production scenarios which implicitly take into account price differentials and other influencing factors. The total technical substitution potential, which can be derived from the material property set of each bio-based polymer and its petrochemical-based equivalent is estimated at 15.4 million tonnes for EU-15, or 33% of the total current polymer production. A more detailed analysis taking into account economic, social, ecological and technological influencing factors relating to the bio-based polymer value chain leads to the identification of three scenarios: WITHOUT P&M (policies and measures), WITH P&M and HIGH GROWTH. In absolute terms, bio-based polymers are projected to reach a maximum of 1 million tonnes by 2010 in the scenario WITHOUT P&M and max. 1.75-3.0 million tonnes by 2020 in the scenarios WITH P&M and HIGH GROWTH respectively. These (physical) amounts are equivalent to an estimated maximum (monetary) production volume of roughly 1-2 billion EUR by 2010 (scenarios WITH P&M and HIGH GROWTH) and 3-6 billion EUR by 2020 (scenario HIGH GROWTH).

While these are sizable quantities, they are modest compared to the expected production increase of petrochemical polymers by 12.5 million tonnes by 2010 and 25 million tonnes by 2020. Thus, the market share of bio-based polymers will remain very small, in the order of 1-2% by 2010 and 1-4% by 2020. This means that bio-based polymers will not provide a major challenge, nor present a major threat, to conventional petrochemical polymers.

Energy and GHG emission savings from bio-based polymers in specific terms were found to be 20-50 GJ/t polymer and 1.0-4.0 t CO_{2eq}/t polymer respectively (Chapter 4.2.1). Bio-based polymers are thus very attractive in terms of specific energy and emissions savings. In absolute terms, savings are rather small: as a proportion of the total EU chemical industry, energy savings amount to 0.5-1.0% by 2010, up to a maximum of 2.1% by 2020; compared to the total EU economy the figures are 0.1% until 2010 and 0.2% until 2020 (Chapter 4.3.1). Greenhouse gas emissions savings amount to 1-2% by 2010, up to a maximum of 5% by 2020; compared to the total EU economy the figures are 0.1% until 2010 and 0.2% until 2020. Bio-based polymers therefore cannot offset the additional environmental burden due to the growth of petrochemical polymers (there is a gap of a factor of about 20 to 40). It is also out of the question that, within the next two decades, bio-based polymers will be able to meaningfully compensate for the environmental impacts of the economy as a whole. However, it is not unthinkable that the boundary conditions for bio-based polymers and the energy system will change dramatically in the decades after 2020, e.g. due to substantially higher oil prices. If, *ceteris paribus*, bio-based polymers would ultimately grow ten times beyond the HIGH GROWTH projection for 2020 (i.e., to about 30 million tonnes), this could avoid half of the chemical sector's current GHG emissions, without accounting for major technological progress (efficiencies, yields) in the decades after 2020. These considerations for the very long term do not justify any concrete (policy) action today, they are rather intended to demonstrate the implications of the comparatively low production volumes until 2020 (compare also per capita values in Table 3-7).

The results of the calculations on land use requirements (Chapter 4.3.1) show that by 2010 a maximum of 125,000 ha may be used for bio-based polymers in Europe and by 2020 an absolute maximum of 975,000 ha (High Growth Scenario). Comparing this with total land use in EU15 for various purposes shows that, if all bio-based polymers were to be produced from wheat, land requirements as a percentage of total land used to grow wheat range from 1% WITH P&M to 5% in the case of HIGH GROWTH. As a proportion of total cereals these figures are a factor 2 lower. Compared to total set-aside land (1997 values), the percentage of land required ranges from 3.6% to 15.4%; as a percentage of industrial crops the range is similar. Bio-based polymers are thus seen to have modest land requirements and will not cause any strain within the EU on agricultural land requirements in the near future. As a consequence the employment potential in the agricultural sector is also very limited until 2020.

Summarising the potential environmental and socio-economic effects it may be concluded that while environmental effects in specific terms are high, effects in absolute terms relative to those of total industry or society are low. Job creation potential is also low. It must be emphasized that these relatively low contributions have their reason in the comparatively low production volumes of bio-based polymers until 2020. Even so, the societal ramifications may be significant and positive in the "green chemistry" arena, for education, for the image of the companies involved (including producers and users of bio-based polymers) and ultimately also for the innovation climate.

The interviews and workshop held within the scope of this project also showed that it is not sufficient simply to lower the cost of bio-based polymers production and facilitate their market introduction. It is equally important to accompany this with R&D activities in the field of polymer processing: Processors also must have access to the relevant additives which should be biodegradable, in order for the biopolymer to be fully biodegradable (examples given: dyes, anti-static additives).

The production of biobased polymers is an emerging sector of industrial biotechnology, both in terms of public and private R&D as in first product niche markets such as e.g. packaging or car-interior fittings. The environmental impacts of biobased polymers in terms of energy and GHG emission savings compares favourably to petrolbased polymers. Targeted policy measures could have a stimulating impact similar to those already in place to support the uptake of renewables in energy production.

However, the implementation of such measures can be difficult. If for instance tradable certificates are discussed, the complexity of the chemical processes and products in question requires a sophisticated monitoring and verification system. The associated costs could easily outweigh the achieved environmental benefits. These problems could be avoided through simpler generic measures such as VAT reduction, focused publicly R&D funding, standardisation of products and processes, and campaigns aiming at raising public awareness. More difficult to implement and to assess with regards to its efficiency is the support of the production of biobased polymers through integration into existing policy schemes, such as the common agricultural policy, the climate change policy and waste resp. waste management related legislation.