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nova Institute
for Ecology and Innovation

Bio-based plastics convince with high climate protection potential and low use of fossil resources

A meta-analysis of 30 life cycle assessments by the nova-Institute for innovation and ecology on behalf of the Proganic company shows unambiguously positive results for the widespread bio-based plastics PLA and PHA/PHB.

Since bio-based plastics have increasingly established themselves and been showing two-digit growth rates, there is a growing public discussion whether these new plastics that are based on biomass instead of mineral oil, really do have ecological advantages – or not. The Proganic GmbH & Co. KG company which exclusively relies on bio-based plastics and has already managed to place different product lines such as garden and household goods on the market, wanted to figure it out exactly and entrusted the nova-Institut (Hürth/Rhineland) with conducting a comprehensive meta-analysis of PLA and PHA/PHB, thus answering the question of ecological assessment based on the latest state of science. Oliver Schmid, managing director of Proganic: "More and more customers are interested in bio-based solutions, but only in those possessing distinct ecological advantages. We owe it to our customers to generate reliable data and make these available to them."

The Proganic® material used by Proganic consists of the bio-based polymers PLA and PHB as well as minerals and carnauba wax. So the nova-Institut in the Meta-LCA looked at polylactides (polylactic acid, PLA) and polyhydroxy fatty acids (polyhydroxyalkanoate, PHA, and especially polyhydroxybutyrate, PHB), both widespread bio-based plastics with a wide range of application.

The use of non-renewable fossil raw materials is a central topic in current political debates: On the one hand, as a result of the use of these raw materials, according to scientific findings the emission of greenhouse gases leads to severe impacts on the global climate system with unpredicatble consequences for the world population. On the other hand, the depletion of fossil raw materials leads to rising raw material prices, economical dependencies and political unrests. That's why customers increasingly put emphasis on buying ecologically and ethically acceptable products.

The result of the meta-analysis of 30 life cycle assessments of PLA and PHA/PHB

The production of the bio-based polymers PLA and PHA/PHB provides ecological advantages compared to the production of petrochemical plastics: The emission of greenhouse gases and also the use of fossil raw materials are definitely diminished. Therefore the substitution of petrochemical plastics with bio-based plastics yields positive impacts in the impact categories climate change and use of fossil raw materials – two criterions that are playing a major role in current political and public discussion. Michael Carus, co-author and managing director of nova-Institut, did express his surprise: "After the excited public debates of recent months we hadn't expected such a clear result, the more so as bio-based plastics are still at the beginning of their development. So the meta-analysis not only shows the advantages already existing today, but also the substantial ecological potential as a result of further process optimisations."

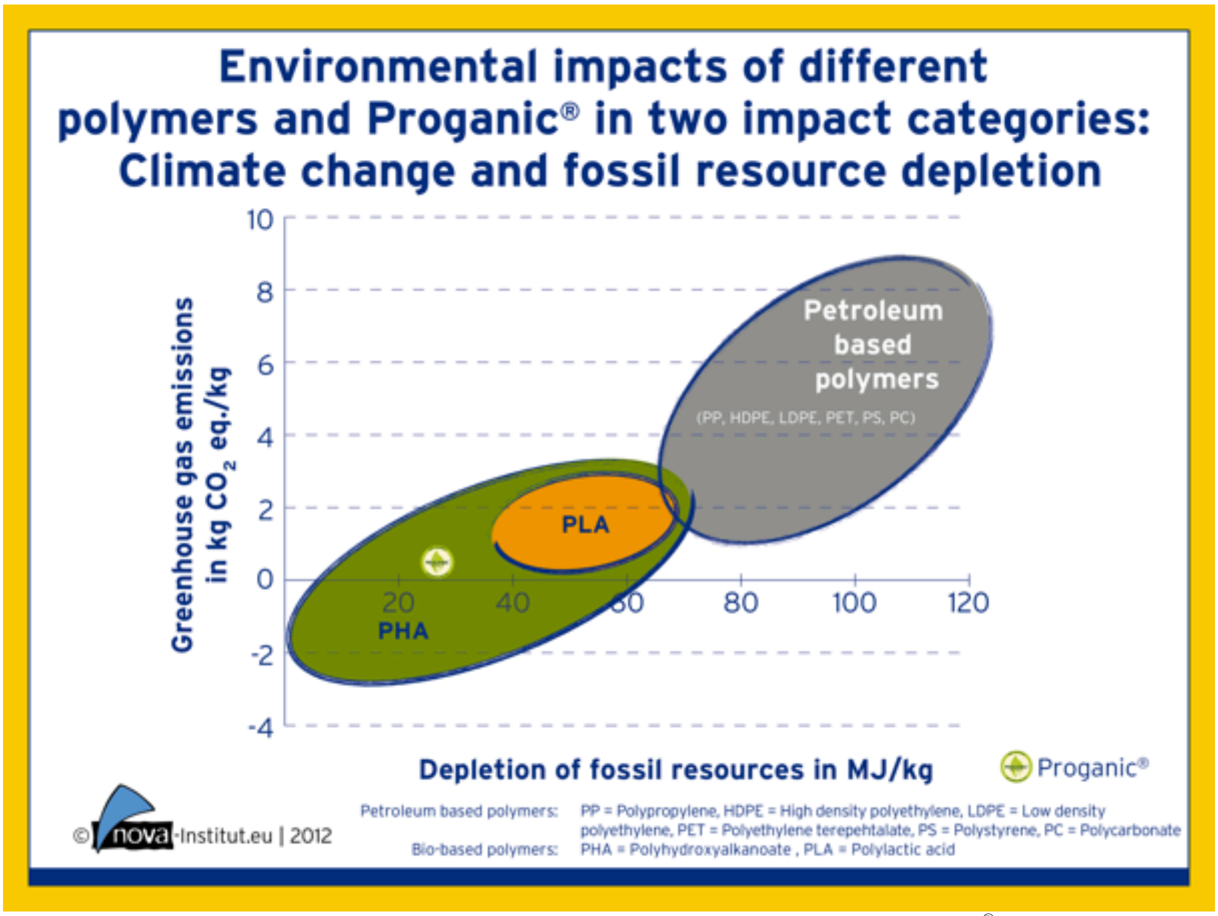

Figure 1: Comparison of environmental impacts of different polymers and Proganic® in the impact categories climate change and fossil resource depletion

Figure 1 shows three ellipses separated from one another that are depicting the clusters of results. The ellipse on the upper right, which contains data with a use of fossil resources of more than 70 megajoules per kilogram plastics and greenhouse gas emissions of partly clearly more than three kilograms CO_2 equivalents per kilogram plastics, correlates to petrochemical plastics. The other two ellipses illustrate the results of the bio-based plastics PLA and PHA/PHB, the data of which for the use of fossil resources are lower than 70 megajoules per kilogram plastics. At the same time the greenhouse gas emissions of bio-based plastics amount to clearly less than three kilogram CO_2 equivalents per kilogram plastics. The ellipse of PHA/PHB exhibits a considerably wider spreading of results than the ellipse of PLA.

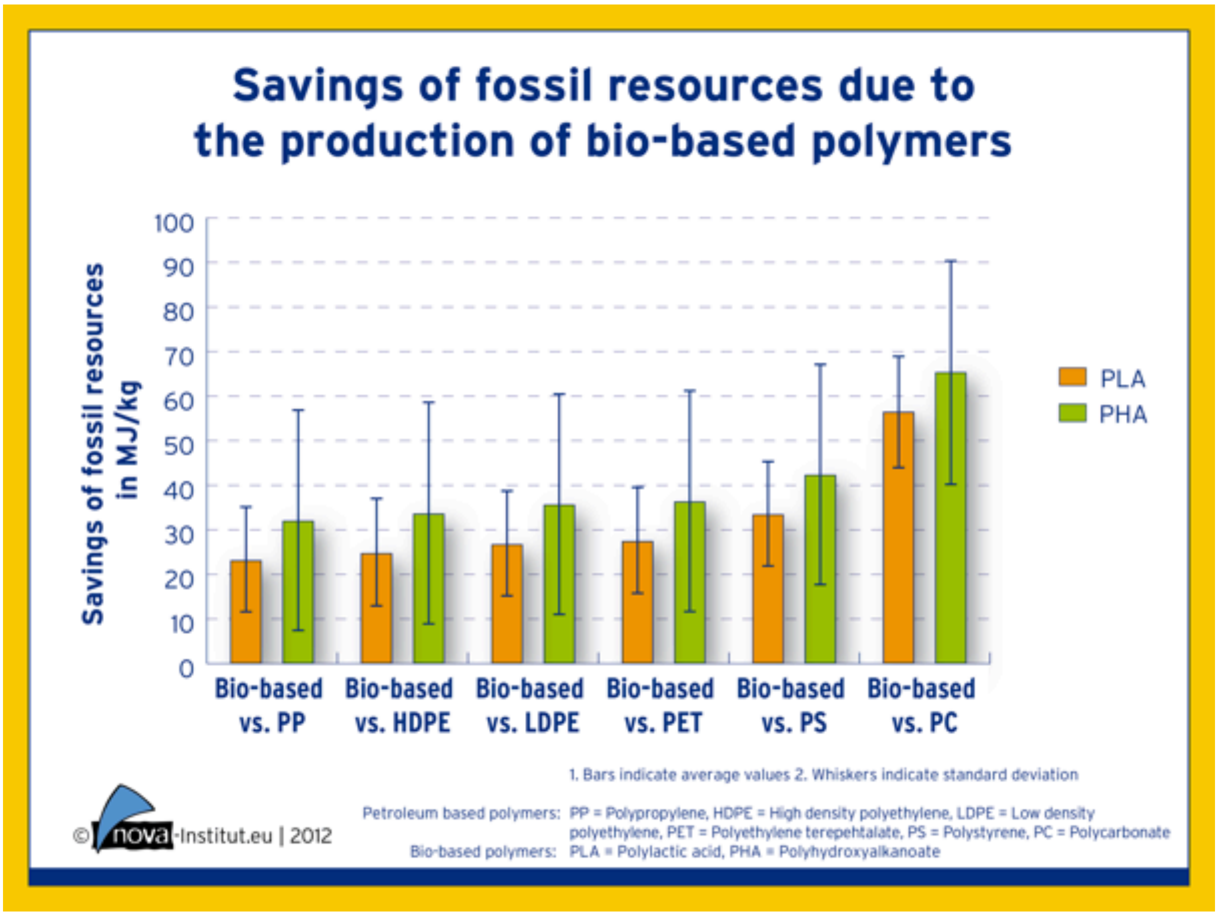

Figure 2: Savings of fossil resources due to the production of bio-based polymers in comparison to the production of petrochemical polymers

Figure 2 shows that the production of bio-based polymers, in comparison to all petrochemical plastics examined, leads to savings in fossile rescources. The biggest savings potential can be found in comparison to polycarbonate (PC). The average savings potential in the production of PLA amounts to 56 ± 13 megajoules per kilogram plastics here. The average savings potential in the production of PHA compared to PC amounts to 65 ± 25 megajoules per kilogram plastics. But also in comparison to PP, HDPE, LDPE, PET and PS, average savings amounting to between 20 and 40 megajoules per kilogram plastics are to be expected.

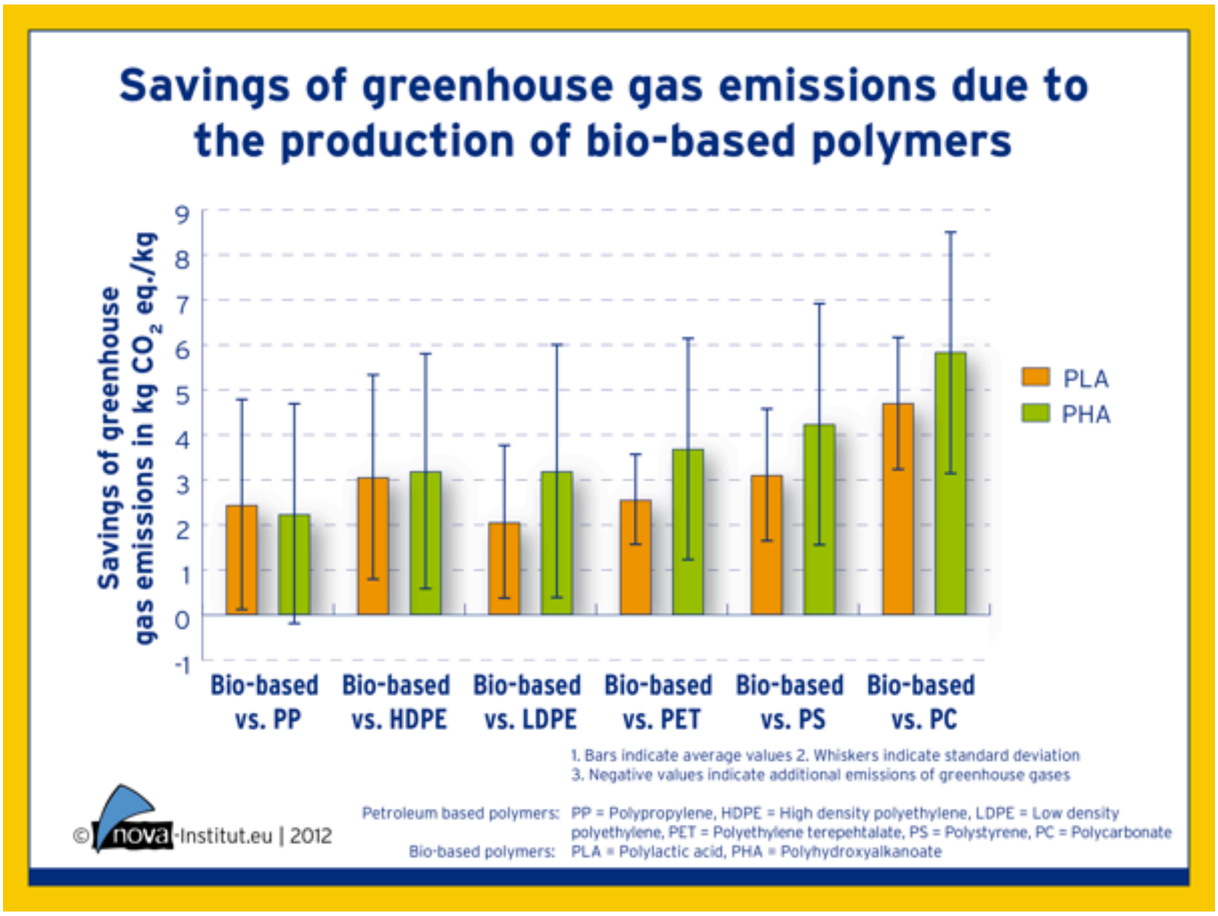

Figure 3: Savings of greenhouse gas emissions due to the production of bio-based polymers in comparison to the production of petrochemical polymers

Figure 3 shows that the production of bio-based polymers in comparison to the production of petrochemical plastics in most cases leads to greenhouse gas emission savings also. The biggest greenhouse gas emission savings can be found again when comparing bio-based polymers to polycarbonate (PC). For PLA, the average savings potential in this case amounts to 4,7 ± 1,5 kilograms CO_2 equivalents per kilogram plastics. For PHA, the average savings potential in this case amounts to 5,8 ± 2,7 kilograms CO_2 equivalents per kilogram plastics. In comparison to PET and Polystyrol (PS), considerable savings potentials ranging between 2.5 and 4.2 kilograms CO_2 equivalents per kilogram plastics are to be found in the production of bio-based polymers. The lowest savings potential are to be found when comparing bio-based polymers to Polypropylene (PP).

Results for Proganic®

What do these results mean for the Proganic® compound? For this, the nova-Institut has made a simple model calculation, to be able to estimate the environmental impact of Proganic® in the impact categories mentioned. The Proganic® material consists of PLA, PHB, minerals and carnauba wax. The greenhouse gas emissions and the use of fossil resources in the production of Proganic® are significantly determined by the components PLA and PHB. For the model calculation, in both impact categories the data of NatureWorks LLC and Metabolix Inc were used. For the minerals, a greenhouse potential of 75 kilograms CO_2 equivalents per kilogram mineral is premised. From carnauba wax, having the lowest mass fraction, no relevant influence is to be expected. Furthermore the compounding processes and transports were included in the calculation.

The result: Calculating the greenhouse potential of Proganic® yielded an amount of 0.5 kilograms CO_2 equivalents per kilogram of that bio-based material. The use of fossil resources was calculated at 27 megajoule per kilogram Proganic®. That means: If the production of PLA and PHB, in comparison to the production of petrochemical plastics, leads to lower greenhouse gas emissions and lower use of fossile resources, this is to be expected for Proganic® itself also, according to our calculations. In figure 1, one can see the respective values marked with the company logo of Proganic®.

Further results of the Meta-analysis

Compared to bio-based plastics, petrochemical plastics have already come a long way of development. For this reason one can assume that the learning curve for an efficient production of bio-based polymers in the coming years will rise to the same degree as the bio-plastics market is expected to grow.

Along with that, the need for research increases, particularly the need for advancing methods for assessing the environmental impact of bio-based polymers. In addition to the development of standards for taking into account the temporary storage of carbon in bio-based products, there is a lack of knowledge with regard to the impact of indirect changes in land use as well as the carbon dynamics on agricultural land. Sensitivity analyses and dynamic models can make a positive contribution to advancing the existing methods.

The results of the meta analysis show that the environmental impact of bio-based polymers also depends on the respective renewable resource basis. The question what renewable resources cause the lowest environmental impact, however, cannot be conclusively answered due to the poor data base. But in general one can say that the use of by-products does improve the area efficiency of renewable resources and thus the life cycle assessment of bio-based polymers. Here the use of agricultural by-products (e.g. corn straw, sugar cane bagasse, etc.) for the generation of process energy (heat, power) improves the life cycle assessment as well as their utilisation as an additional source of raw material (2nd generation biopolymers).

Methodology for the ecological assessment of bio-based and petrochemical plastics

The life cycle assessment (LCA) method is used to analyse the ecological impacts of a production system; it is internationally standardised (ISO 14040). A meta-analysis of different life cycle assessments for bio-polymers such as PLA and PHA, in contrast to looking at only one single ecobalance, makes it possible to give an overall view of the ecological pros and cons of the use of PLA and PHA in comparison to the use of polypropylene and other petrochemically based plastics.

A meta-analysis is a statistical method to depict similarities and differences in the results of different studies and to analyse the reasons for their respective nature and extent. Due to the particular importance of the topics use of fossil resources and climate protection in the public debate, the content focus of the meta analyis is restricted to two categories of ecological impacts.

Here the use of fossil resources is understood to include all fossil resources that are materially or energetically used for the production of the plastics (in MJ/kg). The greenhouse potential, expressed as CO_2 equivalents per kilogram plastics, serves as an indicator for climate protection.

The studies looked at are so-called „cradle to gate“ analyses, i.e. the environmental impacts looked at are analysised from the cradle (e.g. the cultivation of renewable resources) to the factory gate (e.g. preparation of plastic resin). So all subsequent phases of the product life cycle, such as the utilisation phase or the disposal phase, remain unconsidered in most of the studies.

In the meta-analysis conducted, more than 30 studies on the ecological assessment of the production (material and energy flows, preliminary products) of polylactides (PLA) and polyhydroxy fatty acids (PHA/PHB) were examined, evaluated and their results compared to one another. That makes it possible to generalise statements and to draw reliable conclusions with regard to the strengths and weaknesses of the production systems analysed.

The impact categories looked at in the meta-analysis are the use of fossil resources and climate change. When looking at further impact categories, also ecological drawbacks may be revealed in the production of bio-based polymers – as it is unavoidable with any kind of industrial use of biomass, already through the agricultural cultivation of renewable resources.

The full study **„Meta-analysis of life cycle assessments for bio-based polymers in the production of Proganic®“** can be downloaded for free at:
www.bio-based.eu/ecology

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