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Towards a sustainable biobased industry – Highlighting the impact of extremophiles

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ABSTRACT

The transition of the oil-based economy towards a sustainable economy completely relying on biomass as renewable feedstock requires the concerted action of academia, industry, politics and civil society. An interdisciplinary approach of various fields such as microbiology, molecular biology, chemistry, genetics, chemical engineering and agriculture in addition to cross-sectional technologies such as economy, logistics and digitalization is necessary to meet the future global challenges. The genomic era has contributed significantly to the exploitation of nature's biodiversity also from extreme habitats. By applying modern technologies it is now feasible to deliver robust enzymes (extremozymes) and robust microbial systems that are active at temperatures up to 120 °C, at pH 0 and 12 and at 1000 bar. In the post-genomic era, different sophisticated "omics" analyses will allow the identification of countless novel enzymes regardless of the lack of cultivability of most microorganisms. Furthermore, elaborate protein-engineering methods are clearing the way towards tailor-made robust biocatalysts. Applying environmentally friendly and efficient biological processes, terrestrial and marine biomass can be converted to high value products e.g. chemicals, building blocks, biomaterials, pharmaceuticals, food, feed and biofuels. Thus, further application of extremophiles has the potential to improve sustainability of existing biotechnological processes towards a greener biobased industry.

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Introduction

In the face of global challenges, a rethinking process was initialized and strategies towards a sustainable biobased industry were developed in several countries across the globe [1,2]. As defined by the European Commission, these challenges are the growing global population, rapid depletion of many resources,

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increasing environmental pressures and climate change [3]. Further challenges addressed in current literature comprise energy security, food and water security and soil destruction [4]. Therefore, long-term objectives for the transition to a global bioeconomy will be to ensure food and health security, make energy provision more sustainable, make more efficient use of resources and produce new biobased materials [5]. Thus, the ecological acceptability of the whole value chain is one of the key aspects that need to be considered in future designs of bioeconomy. The intended transition from an oil-based to a biobased economy can only be achieved if research centers, universities, politics, industry and civil society are willing to work together on national and international level. An interdisciplinary approach is crucial to develop sustainable and integrative bioeconomy policy strategies [1].

Initial concepts towards greening of industrial processes included the biorefineries, which took traditional oil-based refineries as a model for the development of refineries that use renewable resources as feedstock [6]. In the beginning, starch-containing biomass was utilized for the production of biofuels. First-generation biorefineries thus entailed the discussion whether or not potentially edible biological material should be applied for the production of energy [4]. However, this problem could be solved by switching to lignocellulosic biomass, such as agricultural residues, energy crops and woody materials, as sustainable substrates. Lignocellulosic substrates are the most abundant organic materials on the planet [7]. Besides terrestrial biomass, marine biomass, including micro- and macroalgae, are proposed as renewable resource for a regenerative bioeconomy.

Among the biggest drawbacks in current application of lignocellulosic feedstock as substrate are the recalcitrance of the material and the resulting necessary pretreatment, respectively. Lignocellulose consists of three main constituents: cellulose, hemicellulose and lignin. The fractionation of these components is essential for an economic processing of the biomass [7]. Although the required fractionation can be achieved by various pretreatment strategies, recalcitrance of lignocellulosic materials remains a problem, since state-of-the-art pretreatment steps are too expensive. The development of efficient, environmentally friendly and low-priced processes for the pretreatment of lignocellulosic materials thus forms a major task on the way towards a broader application of sustainable biorefineries in a future bioeconomy [7]. In this context, the low lignin content of macroalgae and its resulting reduced recalcitrance presents another benefit of this so-far underexploited marine biomass. Other important sectors delivering feedstock for a biobased economy are the food and waste industries. Especially in the food industry enormous amounts of waste streams are generated in various processes. Here, several problems could be simultaneously overcome: generating cheap feedstock for biorefineries, reducing energy consumption and the amount of waste that needs to be deposited. This is in accordance with the principle of the bioeconomy to enable economic growth decoupled from increasing greenhouse gas emissions as major reason for the anthropogenic climate change [4]. Enhanced by a growing public awareness of the climate change and related global problems caused by exploiting the Earth's limited fossil resources, policy makers have now started to change course and face the challenge to overcome

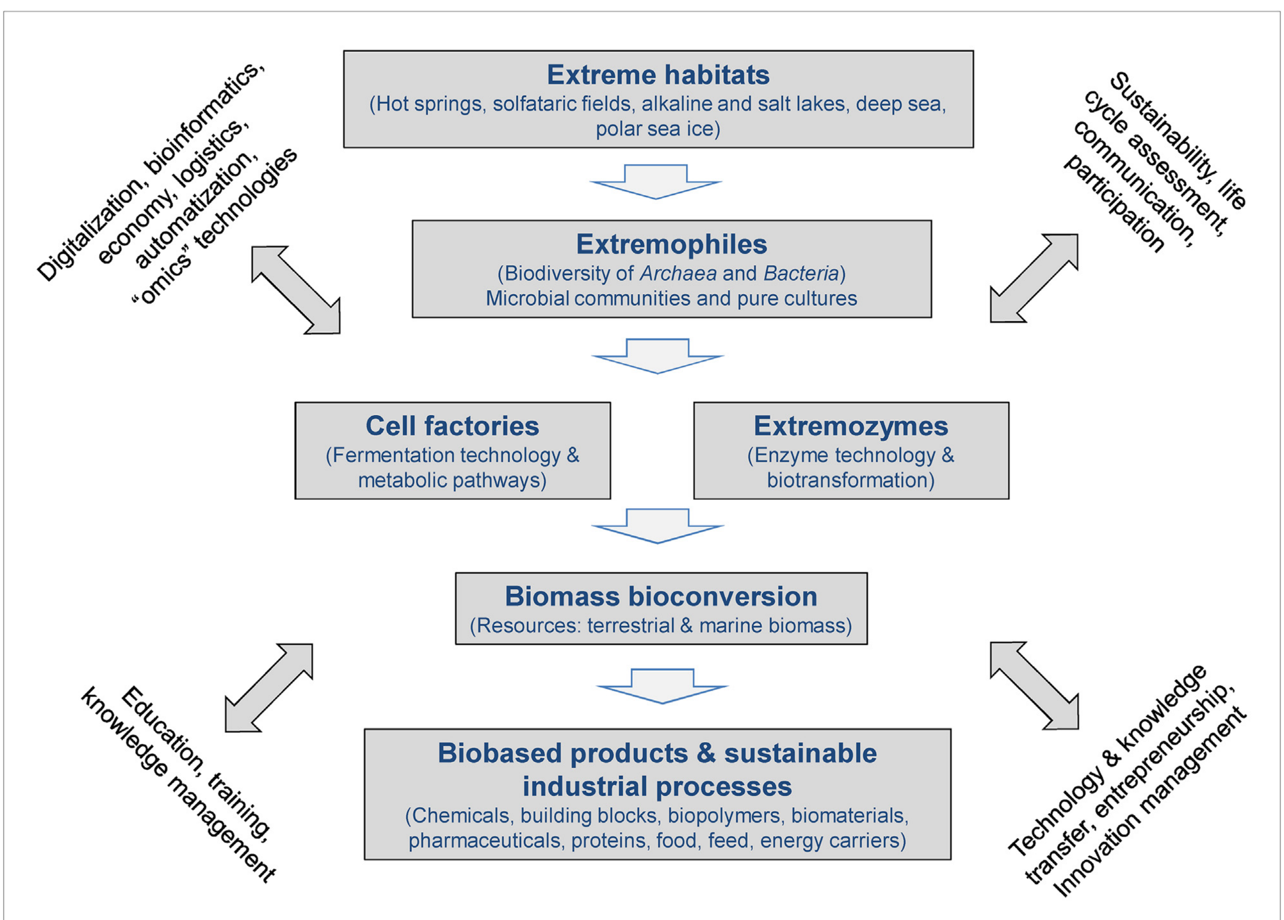

Fig. 1. Contributions of extremophiles and their enzymes to bioeconomy. Cross-sectional technologies and other factors influencing a new emerging bioeconomy.

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