**Bio-Economy:   
Chances, Challenges, and Perspective of the System as a Whole.**

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**Highlights**

* Faster growth of world population than expected results in increased challenges for sustainable development.
* Bio-based economy competes with food production for land area, third-generation biomass cannot fulfill the demands.
* Bio-based economy will have sufficient options to be globally realized.
* Bio-energy will strongly compete with food production.

**1. Introduction**

Humanity is facing grand challenges: we have to reduce the consumption of fossil resources and replace them with sustainable technologies. This implies the use of sustainable raw materials in the chemical industry as well, such as bio-based raw materials or carbon dioxide. Much has been published on the various options for raw materials and technologies to be used. Why one or the other of the many options is more promising than another may not always be obvious.

**2. Approach taken**

In order to get a realistic insight, balances on available resources are used to gain a holistic picture allowing to answer, how the demands of humanity can be fulfilled. The considerations take into account the general challenges of mankind, namely climate change, energy utilization, and world hunger. The balances build on publicly available data like the FAOSTAT database of the UN. The limits considered are the carbon-dioxide emissions to the atmosphere and the land area required for production of food, bio-energy, and feedstock for the chemical industry. The main raw-material and technology options are discussed and related to these boundary conditions and among each other. For the chemical industry the focus is on mass products such as plastics. Some promising main routes are described, and the practical challenges of their realization are addressed, e.g. supply, conversion and distribution. From these interrelationships the societal responsibilities can directly be deduced.

**3. Conclusions**

It turns out that the global population growth is significantly faster than usually considered, because major studies don’t take the continual slight upward shift in the projection of the UN – which are typically applied – into account. Thus the demand side for resources and the waste produced are underestimated. A high population growth has to be considered at least as one bounding scenario.

Based on different population perspectives, the energy demand is considered and coupled with projections on sustainable energy transition. The results show that the energy transition may be possible but will be significantly more demanding than e.g. projected by the Intergovernmental Panel on Climate Change. The efforts, i.e. the rate at which fossil energy systems are replaced by renewable energy technologies, need to be increased by a factor of five in the EU and a factor of almost 10 worldwide. This means that the time-scale of the change has to be some few decades at most, during which also a bio-economy would need to be established.

Considering land area as scarce resource shows that food supply will be challenging, even, if the agricultural efficiencies are continually increased. Thus, bio-energy should not be fostered to a degree proposed in various scenarios, e.g. also those of the EU.

Finally, these considerations set the scene to discuss the available options for bio-based feedstock for the chemical industry. Different crops are compared and combined with different technological options to analyse, if it will be possible to develop a bio-economy without further increase in world hunger. The results show e.g. that third generation biomass will not be sufficient to supply a majority of the feedstock required. Thus competition with food production for land area is unavoidable. At the same time various options exist which will allow bio-based products with only limited land-area use, see Fig. 1. Of course a suitable mix of the different options wll finally be realized, taking into account climate and soil situation. The options are discussed and related, also considering technological maturity of the resulting processes.



**Figure 1.** Required land area for a bio-based economy assuming that each path supplies individually the required feedstock.

Along the way, also the utilization of carbon dioxide is evaluated, which can obtained from the atmosphere in a sustainable economy. For the chemical activation of carbon dioxide, energy, presumably in the form of hydrogen is required, which in turn needs a significant additional contribution from renewable energies. This is related to the effects and consequences of bio-economy.