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CHALLENGES OF IMPLEMENTING A EUROPEAN BIOECONOMY BASED ON FOREST RESOURCES: NEED FOR CIRCULARITY

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ABSTRACT

Greenhouse gas emission reduction is strongly advocated within the European Union. The study of natural communities (biocenology), additionally demands inclusion of a circular economy, in which renewable products are kept in continuous circulation of use and reuse. In light of this, there arises the question whether the bioeconomy route alone, promoted by the EU, is sustainable. Using literature, based on the Delphi method, and EU documents, we highlight the importance of sustainable management of bioresources. It seems that only limited mitigation of greenhouse gas emissions can be expected.

Keywords: bioeconomy, circular economy, forest resource, biofuels, European sustainability, sustainability

INTRODUCTION

Contributing to greenhouse gas emissions reduction, is concurrently possible mainly by substitution with low carbon products, increasing energy and materials efficiency and recycling of materials and utilisation of waste. The key challenge on a global level is how to generate a sustainable approach in utilising natural resources, especially biomass neutral [4, 23]. The EU has set a milestone for cutting its carbon emissions by 2030 to levels 40 % below the levels of 1990 through domestic consumption reductions, the greater use of renewable energy sources with implementation of the bioeconomy as a means for addressing environmental problems [1, 4, 10].

The forest industry is expected to lead technological development and implement changes towards a bio-based technology by concentrating on the use of biomass, considering it to be itself renewable, thus merging the forest sector with the technology sector [2, 11, 14]. It is expected that the bioeconomy sector will create a whole new range of products via the implementation of biomaterials that utilise novel developments, such as nanocellulose, man-made fibres from lignocellulose and cellulose waste and replacement of fossil fuels-based polymers with biopolymers [15, 25].

METHODS APPLIED IN PROPOSED EVALUATION

The method used by the actors in the field for conducting the relevant analyses mainly follows the Delphi approach for data collection as an appropriate means of long-range (20–30 years) academic research, together with expert opinions. State of the art literature on biotechnology regulatory and bio-based materials development is also reviewed to help in understanding the trend in development of novel technologies.

SUSTAINABILITY DEVELOPMENT SO FAR

To reduce waste and green gas emission impact on climate change, governments around the world have started adopting so-called ‘biotechnology strategies’ with an aim to set up plans and legislation for the investment in technological development designed for the implementation of sustainably manufactured goods and biofuels. Implementation of the EU bioeconomy emerges as a *quasi*-trade mark of the European answer to environmental problems. Its development from the idea towards defined technological and economical routing took over three decades. It has evolved through carefully planned marketing and research funding activities towards achieving bioeconomic stability [4, 5].

A visionary cycle was seen to emerge in the EU in 1993 towards development of the bioeconomy policy framework, with the EU White Paper entitled "Growth competitiveness employment: the challenges and way forward into the 21st century", which advocated the necessity for biotechnology in innovation and growth [5]. Later, the Lisbon Agenda from 2000 emphasised the need for EU leadership in the global 'knowledge-based economy', that would decrease its dependence on fossil oil [4, 10]. The 2002 EU bioeconomy strategy followed, promoting life science and biotechnology as the likely most promising of the frontier technologies, with a capacity to contribute to the achievement of the Lisbon Agenda objectives. In 2005 the 'knowledge-based bioeconomy' (KBBE) was finally established. It took until February 2012 for the European Commission to publish an action plan of bioeconomic development, entitled, "Innovating for Sustainable Growth: a bioeconomy for Europe" in which bioeconomy was portrayed as an environmentally acceptable solution to a variety of European and global problems, following the same trend *at that time* in the United States [12, 20, 25].

In the case of the forestry sector, environmental regulation has played a large role helping with the transition in the EU towards sustainable societies and green growth (see, for example, Forest Sector Technology Platform, 2015) [26]. The increased use of forest biomass for production of biofuels is expected to boost European Economy and is explicitly supported by forestry policies at EU level and especially in the Nordic and Baltic countries [11, 14, 21], considering that these regions are extremely rich in forests.

BIOFUELS FOR SUSTAINABLE REDUCTION OF GREENHOUSE GASES – current status

Factors that help promote biofuels and place them into the global fuel market are: expected increase in population and thus fuel demand, decrease in fossil fuel reserves, and already observable climate change accrued to the model of global warming [1, 24].

By 2030 the global population is expected to increase by 1.3 billion inhabitants on top of the 7.6 billion currently, with growth predominantly in developing countries, which will have a rising middle class without any proper mindset of sustainable consumption of goods and transport, which will create additional stress from pollution, inefficient land use and food production [19, 20, 23]. The global production and use of biofuels have increased dramatically in recent years, with about 85 % of their production going to bioethanol manufacture, considered the most ecologically friendly liquid biofuel, that can be produced from a variety of cheap raw materials that are sugars chemically. Theoretically, ethanol represents a closed carbon dioxide cycle because released carbon dioxide (CO_2) from ethanol burning is recycled back into plant material during photosynthesis subsequently to become biomass [26]. Sugars, such as cane and molasses, can be used directly for ethanol production via fermentation, while starches, from corn, potatoes and root crops, must be hydrolysed via enzymes to fermentable sugars, and only then ethanol can be produced [3, 8]. Cellulose, from wood, agricultural residues, waste sulphite liquor from pulp and paper mills, must likewise be converted into sugars, generally by the action of acids or cellulolytic enzymes [11]. Lignocellulose biomass has long been advocated as a feedstock for cost-effective bioethanol production in an environment-friendly and sustainable manner, and agricultural wastes/residues are advocated as abundant and renewable resources for second-generation bioethanol production [9, 11]. Therefore, to make full use of these resources for sustainable and economically feasible bioethanol production, the following difficulties still need to be overcome: (i) collection, supply and handling of bio-waste; (ii) economically feasible pre-treatment of waste; (iii) production of different economically feasible enzymes and yeast strains that will enable more efficient fermentation of cellulose in working conditions [15].

Unlike traditional ethanol production, however, biofuels derived predominantly from forest harvesting potentially lack the equilibrium in respect to CO_2 production and reabsorption. Many scientists claim that balance is only true if the calculated plant base taking up CO_2 is not cut in the first place to create the ethanol, Fig. 1, [23, 24].

Policies that will make biofuels more competitive identify the need for taxation of fossil fuels and fixed prices for biofuel-derived energy that may limit economic growth in the long run as forest biomass is only a slowly renewable source, considering the expected fast consumption of its sources [25].

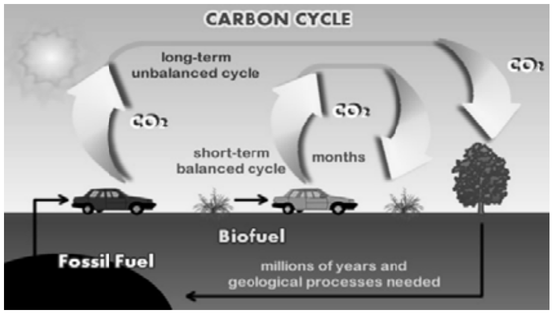

Fig. 1 Carbon cycle of transportation fuels / adopted from [56, 67] /.

MODELLING SUSTAINABLE DEVELOPMENT (SD)

Regulatory environment and megaforces

It is essential to predict the cyclical shift to a new contextual phenomenon, such as a European bioeconomy evolution, and its sustainability development (SD) model [19]. Achievement of full sustainability through SD should be cross-linked with developments of new technologies and the ability to mobilise public interest in their application [3, 10]. As it has always been in human history, a public component is always necessary to push towards technological development and industrial transformation, which form was captured in the representation of Kondratieff waves, as shown in Fig. 2, [12, 19]. On the one hand, a transition to a bioeconomy increases business uncertainty in the future, but on the other hand it is the main driver for creation of shared value of the socially accepted need for economical investment in technology and education necessary for sustainable productivity growth [23].

Taking the relationship between the nature and human species, assuming them to be distinct in a modern protected society, as a parameter that should differentiate existing approaches of SD, there are two paths: (i) conservative or "weak" sustainability, in which nature is considered as a 'resource' and in which humans are supreme above other living species on the planet, natural resources being goods that must be continuously used. The only thing that matters in a weakly sustainable society is the increase of stock and capital [22], which leads to maximising monetary compensations for environmental degradation, and (ii) the second approach, diametrically opposed, environmental preservationist, or 'strong sustainability', in which humans and nature are seen in equilibrium within the ecosystem that respects the value of natural resources and where biodiversity is essential. The proponents of strong sustainability claim that any utilisation of natural capital can never be sustainable, and that manufactured capital that requires an increase of future consumption of forest biomass for the bioeconomy needs is not an appropriate argument for destroying natural resources such as water, land, air and diverse habitat forests [26]. From a short-term temporal perspective, large investments are necessary to push for development of biotechnologies and business, with inevitable conflict between the economical and societal interests and views [11]. For downstream industries, that govern changes in biotechnology, the sustainability megaforces act to emphasise concern over vulnerability related to increasing biomass resource constraints that can cause long-term deforestation and habitat loss [25, 26]. Of increasing concern is that conflicts can arise over raw material prices, availability and sustainability acting as barriers for changing the strategic focus in the capital-intensive forest industry [5, 24, 21]. Further obstacles for strategic renewal towards sustainability are conservative organisational culture and limited financial resources [22].

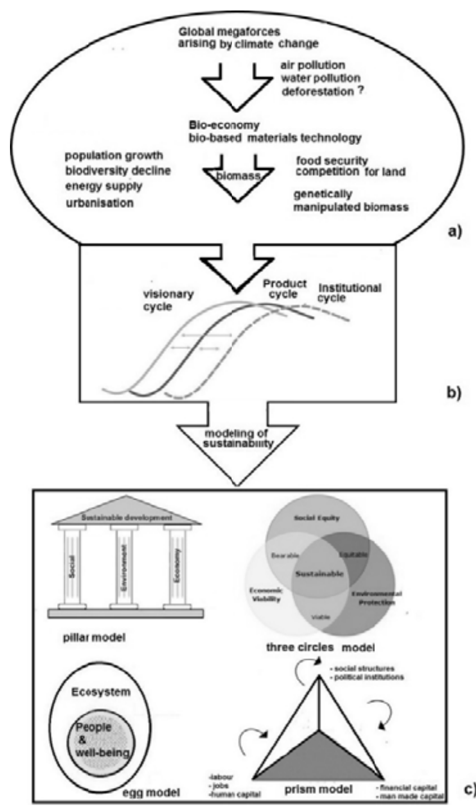

Fig. 2 Schematic presentation of global megaforces that influence changes in society towards sustainable bioeconomy / adopted from [19] /

For predicting how sustainability will act as a future megaforce in the European bioeconomy, and its leading role in the forest industry, it is necessary to understand the role of wood biomass in the production of biomaterials and biofuels, which are being defined as zero total carbon emission products [15, 26].

Model for the European perspective

The European bioeconomy strategy focuses on: food security, natural resources, fossil fuel dependence and climate change. However, when considering the fourth aspect of a sustainability model, which is social development in combination with the research and education policy, it has been observed that the EU Framework Programme 7 (FP7) funding scheme strongly influences national research budgets through setting in motion the European Research Area [11, 13]. However, EU policy has been criticised for enabling access to patent rights from European participating companies, arising from research areas aligned with biotechnology [21]. Furthermore, critics claim that the use of renewable eco-efficient terms synonymously with sustainable gives the impression that all renewable-sourced technologies bring lower air and water pollution and reduced waste [15]. This conflation assumes that forest biomass resources can somehow replace all fossil fuel-derived chemicals, whilst organic waste automatically becomes a new renewable biomass resource, which is naturally, assumed to be always sustainable [22].

As an example, the EU (2013b) blueprint for forest-based industries challenges emphasises the significance of stimulating transition in the industry mind-set with a radical investment in research and innovation area, effecting increased production efficiency and quality of biobased products, with an aim to grow and to be competitive in different markets [24, 26]. At the EU level, the Forest Sector Technology Platform (2015) has recognised new biomaterial-based products as an important research and development area, with strong emphasis on sustainability at an overall and national level [25]. As the country with the largest wood biomass resources in Europe, for example, Finland has established its 2030 roadmap for bioeconomy development towards a carbon-neutral society [2]. The Finnish approach towards bioeconomy is, however, criticised as being too much "business as usual", in which dominant ideas and emphasis on sustainability are characterised as being economically driven and conservative [21, 22].

Over the last years, several strategies have been set forth for establishing more sustainable production patterns, and reduction of solid waste and appropriate use and reuse of natural resources using the circular economy strategy, e.g. European Commission, 2015 [5, 11]. This approach, however, requires highly sophisticated technologies and a high quality of biomass raw materials, excellent waste collection and sorting logistics regionally and internationally. In addition, for the bioeconomy strategy (BMEL, 2014; European Commission, 2012) a value-added oriented hierarchical utilisation of biomass for materials, chemicals, fuels and energy production is prioritised only after the provision of a sufficient healthy supply of food and feed to meet the basic needs of society. The cascading principle of sustainable biomass distribution in the EU bioeconomy is depicted with the "Biomass value pyramid" (Fig. 3) [12]. Key solutions and strategic actions towards a sustainable bioeconomy should include closed-loop recycling of all consumer products and materials, using the circular economy concept [13], that keeps products and materials within the biomaterials pyramid [14]. Changes in living habits are expected to be in tune with the circular economy; for example, recycling of solid-wood products can be increased with increased use of wood and wood composites in building that maintain strength over time, reduction of working and living space, and change in transportation habits, including working from home etc. [10, 23].

A recent study detailed different scenarios of biomass supply and demand in Europe (EU27) and in the world until 2050, compared to the situation in 2016, where worldwide biomass supply in 2050, based on these scenarios, would be between 12.4 and 25.2 billion tonnes of dry matter, in which wood supply would grow from about 2 to about 8 billion tonnes of dry matter, to meet demands of industry and food [20, 26].

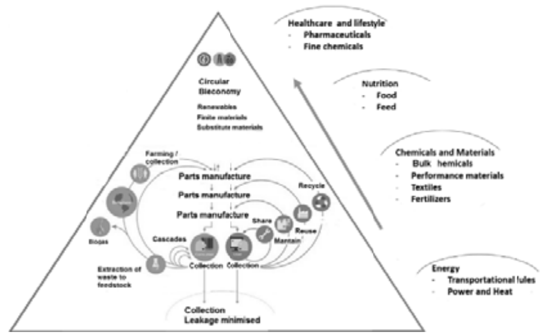

Fig. 3 Schematic illustration of closed loop concept of bioeconomy with cascading concept within the bio-mass values pyramid /adopted from [24] /

Demand for wood biomass for production of biofuels is especially high in European countries, as Europe's lack of oil resources with North Sea reserves depleted and the single dependency on Norway within the Nordic cluster, and on Russia and the Middle East outside the EU, has resulted in an emerging international trade in wood for bioenergy (primarily cut trees) [24]. That demand of wood has been largely satisfied up to now with imports from the USA and Canada, countries that are rich in wood resources and have their own interests in developing wood biofuels [16, 21] with increased investment by European companies in the forest land outside Europe (Asia, South America) with often unsustainable planting methods that utilise exclusively genetically modified (GM) crops [6].

When considering a defined 'sustainable' approach, only the 'low' biomass supply scenario can be regarded as keeping biodiversity at a similar level as today [16, 22]. Even though it is difficult to predict trends in population growth and consumption habits of a world in 2050, it is certain that it is impossible to replace fossil fuels totally in a sustainable way, and more likely other sources of renewable energy must be developed [20].

CELLULOSIC MATERIALS IN THE FUTURE

In the light of the questionable role for biofuels discussed above, it is worth exploring the opportunities for cellulosic nanomaterials, made from renewable sources, as are likely to emerge in a range of applications that contribute to material sustainability. Advantages of low weight result in low carbon emissions in products and transport relative to other materials, whilst at the same time they bring high material strength and stiffness exceeding that of many metals. It has been demonstrated that application of cellulosic nanomaterials drastically increases concrete fracture toughness at addition levels as small as 0.5 wt%, decreasing the need for non-renewable materials use [7, 17, 18].

Speciality markets for cellulose nanomaterials already include flexible printed electronics and light emitting diode (LED) video screens, medical applications such as slow release drug delivery, incorporation in microfluid analytical devices, aerogel preparations for bone and tissue scaffolding, and 3D printing.

CONCLUSIONS

The main driving forces to increase the use of forest biomass for energy and production of bio-based materials are the international concern about climate change and, importantly, the political global imbalance of energy-rich nations as a major cause for potential destabilisation. European countries are becoming increasingly dependent on imported fossil energy. At the same time as demand is increasing, Europe needs to reduce energy costs to be able to reach economic competitiveness in the global market and to provide related social benefits, such as employment, education and health services. In Europe, where many national industries are highly dependent on fossil fuels, forest biomass is considered the solution for improving social security, providing steady material supply and thus economic growth, which will enable the EU to be competitive with the use of forest biomass providing a sustainable and unlimited resource of materials that does not contribute to increased emissions of greenhouse gases.

From the discussion in this overview, clearly the transition towards a bioeconomy is a complex process, that should be the result of concerted and simultaneous development of economic, technological and ecological awareness together with evolution of cultural values on the global scale, so that the EU can be a part of it, whilst maintaining a unique aspect to its competitiveness. This must be considered in the light of sustainability development in countries that the EU imports from or invests into, which directly influences the sustainability development of the EU itself.

The conclusion proposed here, is that a strategy toward a balanced bioeconomy needs to take account of the precepts of biocenology, which inform of the pitfall of ignoring the lack of coupling between human values and the environment occupied by the humanity. This balance can only be achieved by following the precepts of a circular economy, and not by a naïve short-term adoption of the assumption that biomass *per se* alone is sustainable.

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