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Identifying the Challenges of Implementing a European Bioeconomy based on Forest Resources: Reality Demands Circularity

Greenhouse gas emission reduction is strongly advocated within the European Union (EU). Biomass has emerged as a renewable energy source and as manufacturing raw material with ecological credentials to mitigate carbon imbalance. The EU has defined the bioeconomy encompassing these material sources as a basis for technological and economic development. Biocenology, describing the study of natural communities, however, additionally demands inclusion of a circular economy, in which it needs to be assumed that endless renewable products are kept in continuous circulation of use and reuse. Thus, there arises the question whether the bioeconomy route alone, promoted by the EU, is sustainable. Using research literature, based on the Delphi method, and EU documents, we discuss the importance of sustainable management of bioresources. Short term solutions may remain necessary to ensure economic stability but, without embracing the circular economy, only limited mitigation of greenhouse gas emissions can be expected.

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

1. 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, that is also recognised in the EU, is how to generate a sustainable approach in utilising natural resources, especially biomass considered to be CO_2 neutral [1-3]. 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, improved energy efficiency and the greater use of renewable energy sources [4,5]. In parallel, the bioeconomy has been recognised as a means to address environmental problems by concentrating on the use of biomass, forest biomass explicitly, as a main source for the production of renewable energy and goods, considering it to be itself renewable [6,7].

Through increased market globalisation, European countries became exposed to growing competitive challenges whilst attempting to achieve the sustaina–bility image amongst bio-based materials sector compa–nies [1,2]. From the necessity to merge two opposing streams, social well-being defined through sustaina–bility, on the one hand, and economic development through competitiveness of European forest-based business, on the other hand, European countries will have to make large investments and face profit loss in the short term, if they wish to place bio-based products on the market, especially if the main overseas compe–titors are going to continue to produce cheaper fossil fuels-based products [8].

Current political unease is reflected, for example, in the pattern of nationalist retrenchment, largely abandoning the challenge to reconcile market forces with sustainability, which sits contra to the centralised EU moves toward a bio-based economy, regardless of the regional differences in respect to economic development, fiscal resilience and natural resources [9-11].

Even regions with a wealth of natural renewable resources, will encounter huge costs, for example, in the forest sector from the short to medium time perspective: hope remains, however, that this expenditure will lead to economic equilibrium within the emerging bioeconomy once maturity is reached [5,12,13].

The forest industry is expected to lead technological development and implement changes towards a bio-based technology, thus merging the forest sector with the chemical sector, pharmaceutical industry, paper and pulp industry, energy sector, textile industry etc. [9,12,14]. These changes introduce a whole new range of products into the forestry sector existing beside traditional wood products, such as plywood, pulp, pa–per, board and tissue [15,16]. New technologies have already enabled production of novel materials such as nanocellulose, man-made cellulose fibres and impor–tantly fibre reconstruction from cellulose waste [17,18],

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electronics, agricultural fertilisers, paints, tyres and perfumes [19].

2. METHODS APPLIED IN THE QUEST TOWARD EVALUATION

The method used by the actors in the field for con–ducting 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 conducted in respect to develop–ment of bioeconomy and bio-based materials within the EU [20]. A change from fossil-based industrial activity to bioeconomy has been defined in many EU bio–economy policies, which have followed the developing decline in the forestry sector and recognition of the social acceptance of appreciating long term environ–mental consequences [6,15]. From materials collected reflecting these analyses we try to pinpoint future trends in sustainability development within the EU bioeco–nomy, and so shed light on possible long term environ–mental drawbacks associated with a free-market mana–ged bioeconomy [7,21. State of the art literature on bio-based materials development is also reviewed to help in understanding the range of technologies and processes that will be needed [12,16,18].

3. SUSTAINABILITY DEVELOPMENT – HISTORICAL PERSPECTIVE

In tune with visible changes in global climate consi–dered to be associated with greenhouse gas-induced global warming in the early 2000s, governments around the world started adopting so-called ‘biotechnology strategies’ that had an aim to define necessary invest–ment, technological and economic activities aimed at the production of sustainably manufactured goods and fuels. That movement produced a shift from initial formulation proposals for the transition to biotech–nology, via defining policies, toward actually setting a bioeconomy in place [22]. Implementation of the EU bioeconomy as a trade mark of the European answer to environmental problems was a process that took over three decades, evolving from the idea through economic and research funding activities towards achieving bioeconomic policies as a necessary step towards the decrease in fossil fuel consumption and greenhouse gas emission [3,23,24].

Already in 1993, a visionary cycle was seen in the EU towards development of the bioeconomy policy framework, being the product of two decades of eco–nomic and political activities , being set with the EU White Paper entitled “Growth competitiveness employ–ment: the challenges and way forward into the 21^{st} century”, which advocated the necessity for biotech–nology in innovation and growth [7]. Later, the Lisbon Agenda from 2000 emphasised the need for EU leadership in the global ‘knowledge-based economy’, that would secure its competitiveness and economic growth, and decrease its dependence on fossil oil [21, 24]. Next to come was the 2002 EU bioeconomy strategy with the title “Lifesciences and Biotechnology: a strategy for Europe”, prioritising life science and biotechnology as probably the most promising of the frontier technologies, with a capacity to contribute to the achievement of the Lisbon Agenda objectives and in 2005 the ‘knowledge-based bioeconomy’ (KBBE) was finally established [23,25]. In February 2012, the Euro–pean Commission published an action plan of bioeco–nomic development entitled, “Innovating for Sustainable Growth: a bioeconomy for Europe” [17], in which bioeconomy was portrayed as an environmentally acceptable solution to a variety of European and global problems, and in that way ‘bio–economy’ became a central element of the EU's political agenda, following the same trend at that time in the United States [16], [26].

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) [27], [23]. The increased use of forest biomass in energy consumption is explicitly supported by forestry policies at EU level and in the Nordic and Baltic countries [5], [16], considering that these regions are rich in forests, Fig. 1.

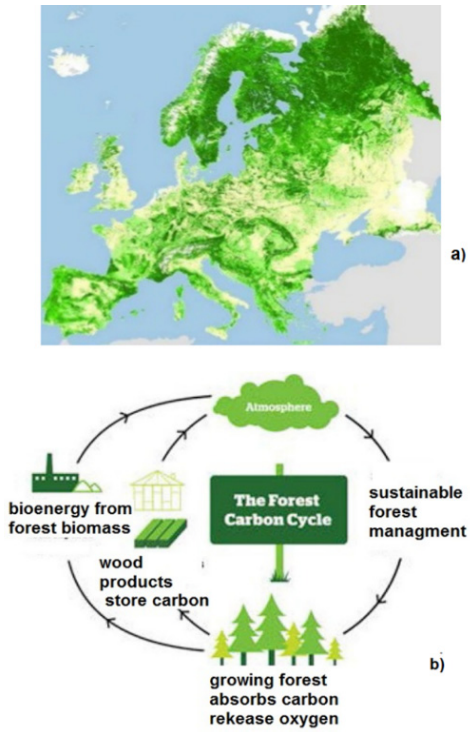

Fig. 1 Bioeconomy recognised biocenologically as a nanocellulose economy based on renewable sources: a) forestation in the EU, b) closed circulation of forest biomass / adopted from referencies / [27], [28], [29] /

4. BIOFUELS FOR SUSTAINABLE REDUCTION OF GREENHOUSE GASES – CURRENT STATUS

Biofuels have established their place as a proposed alternative to fossil fuels to meet requirements for petroleum/diesel/fuel oils in a sustainable manner. Factors that help promote biofuels and place them into global fuel market are increasing fuel demand, decrease in fossil reserves, and most of all global warming and greenhouse gas emissions [29,30]. The global production and use of biofuels has increased drama–tically in recent years, with about 85 % of this being bioethanol [31]. By 2030 the global population is ex–pected to increase by 1.3 billion inhabitants, with rising middle class without any proper mindset of susta–inable consumption of goods and transport, which will create additional stress from pollution, inefficient land use and food production [12,29,32].

Bioethanol is the most common and one of the most ecologically friendly liquid biofuels, suitable for augmenting petroleum, that can be produced from a variety of cheap raw materials [8,20]. Ethanol derived from biomass is considered the only liquid trans–portation fuel that does not contribute to a growth in the greenhouse gas effect [6,25]. 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 [24,30,33]. The varied raw materials used in the manu–facture of bioethanol are sugars, starches and cellulose materials [34]. Sugars, such as cane, molasses, can be used directly for ethanol production via fermentation. Starches, from corn, potatoes and root crops, must first be hydrolysed via enzymes to fermentable sugars [13,27,35,52]. Cellulose, from wood, agricultural resi–dues, waste sulphite liquor from pulp and paper mills, must likewise be converted into sugars, generally by the action of acids or cellulolytic enzymes [13,27,35,52]. Lignocellulose biomass has long been advocated as a key feedstock for cost-effective bioethanol production in an environment-friendly and sustainable manner. Lignocellulose-rich agricultural wastes/residues are abundant and renewable resources for second-generation bioethanol production [24,30,44,57]. There–fore, to make full use of those 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) eco–nomically feasible pre-treatment of waste; (iii) pro–duction of different economically feasible enzymes and yeast strains that will enable more efficient fermentation of cellulose in working conditions [20,34]. Continuous development in technologies for second-generation biofuel production, i.e. more cost-effective and susta–inable lignocellulose and waste to bioethanol con–version by making microbial processes more efficient [1,14,19,25,26,31].

Unlike traditional ethanol production, however, bio–fuels derived predominantly from forest harvesting potentially lack the equilibrium in respect to CO_2 pro–duction and reabsorption. Many scientists claim that this is only true if the calculated plant base taking up CO_2 is not cut in the first place to create the ethanol, i.e. biomass for photosynthesis in this scenario is in fact, at least initially, decreasing continuously, Fig. 2, [3,18, 33]. Policies that will make biofuels more competitive are identify the need for investment support, taxation of fossil fuels, and fixed prices for biofuel-derived energy [21,28]. However, these cost additions and subsidies to harvest forest biomass to make forest-based fuel may well limit economic growth compared to unregulated markets. However, such initiatives might bridge initially high transition costs to bioenergy and in the long run lead to the development of mature bioeconomy markets [4,36,37].

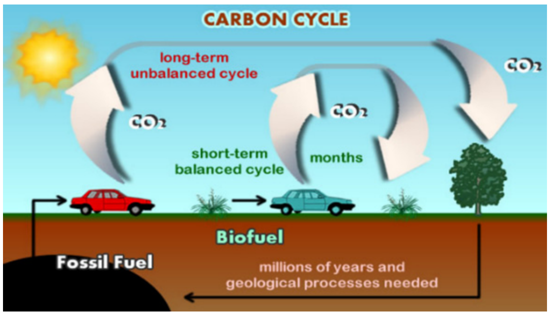

Fig. 2 Carbon cycle of transportation fuels, in terms of time needed for accumulation of fossil fuel versus biofuel from crops / adopted from refrencies / [2,19,56,67].

5. MODELLING SUSTAINABLE DEVELOPMENT (SD) – THE REGULATORY ENVIRONMENT AND MEGAFORCES

Deep inter-linkages between global trends leads to megatrends, in which a change in one aspect is reflected in another [8,38]. Sustainability-oriented regulations can improve competitiveness by driving simultaneously re–source efficiency, productivity growth and shaping all aspects of society as a response to megatrends [2,3, 10,37]. Focusing on previous trends is essential to understanding the cyclical shift to a new contextual phenomenon, such as a European bioeconomy evolution, and its sustainability development (SD) model [33]. Achievement of full sustai–nability through SD should be cross-linked with develop–ments of new technologies and the ability to mobilise public interest in their application [16,36]. As it has always been in human history, a public component is always necessary to push towards technological development and industrial transformation, which was defined with Kondratieff waves, Fig. 3, [36,39]. A model of three waves was proposed to present a road map for development of bio-technological innovations and their applications in the bioeconomy; the first wave is the visionary cycle, in which a new societal vision should develop and mature; secondly a wave representing the product cycle within which innovations are created that will be a stepping stone in technology; and thirdly a wave that is an institutional cycle, which, through politics, formalises organisational frame–works that are necessary to support technological develop–ment and social acceptance [37]. 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 sustainable productivity growth [5,24,33]. There are other different models for SD in the literature, Fig. 3 showing the mostly used ones, ranging from one dimensional, in which there is no time parameter, the wave approach, mentioned above, the three-pillar model (the three pillars repre–senting three key issues – social, environmental and economic), and the three circles model, in which con–centric circles display subsystems that overlap, once again environment, human society and the economy [37]. The egg or well-being model uses an oval or egg metaphor to present the white of the egg as an oval ecosystem that completely encapsulates the people (yellow yolk), and finally the prism model that utilises an SD model including time as the governance dimension or time needed for social acceptance [8,26].

Taking the relationship between the nature and humans, assuming them to be (positively or negatively) 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 conti–nuously used [8,36,37]. The only thing that matters in a weakly sustainable society is the increase of stock and capital [21,39], which leads to maximising monetary compensations for environmental degradation, and (ii) the second approach, diametrically opposed, environ–mental 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 [40]. The proponents of strong sustainability claim that any utilisation of natural capital can never be sustainable, and that manufactured capital requires natural capital for its production (raw materials, land etc.) [27,41]. On the contrary, it can never be a complete substitute for the destruction of the ecosystem that is necessary for human well-being (security, life, health, and good social relations) [33]. Furthermore, an increase of future consumption of biomass for the bio–economy needs is not an appropriate argument for destroying natural resources such as water, land, air and diverse habitat forests [26,34].

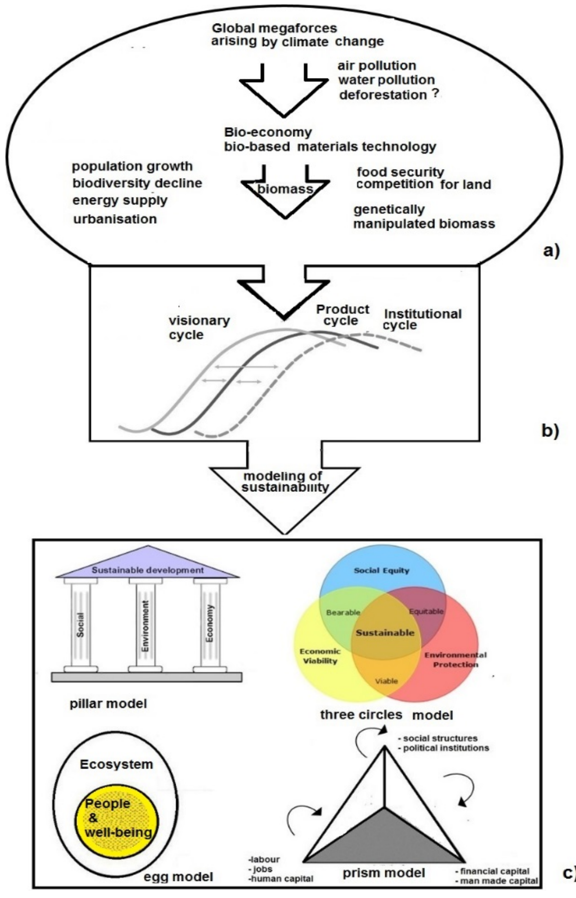

Fig. 3 Schematic presentation of global megaforces that influence changes in society towards sustainable bioeco–nomy development / adopted from refrencies / [7,14, 40] /

A document by KPMG (2012) identifies dimensions under sustainability megaforces that will be implemen–ted in every business, as are pictured also in refs. [7, [22]. In a recent publication, in which EU bioeconomy docu–ments were analysed in order to understand the direction of development in forestry policies it was shown that by 2030 the global population is expected to increase by 1.3 billion inhabitants on top of the 7.6 billion currently [32].

The population growth is expected to be predo–minantly 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 [10,28,42].

From a short-term temporal perspective, large inve–stments are necessary to push for development of biotechnologies and business, with inevitable conflict between the economical and societal interests and views [14,25,43]. For downstream industries, such as Euro–pean forestry, 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, and thus tightening of regulation, e.g. for material transport emissions, mainly greenhouse gases [11,16,29,34]. Key industry opportunities were conclu–ded to originate from sustainability, digitalisation and demographic and lifestyle changes, while the most imminent threats were caused by increased prices due to scarcity, the service industry orientation of the economy and perhaps also sustainability trends, such as attitudes to avoiding packaging waste. In a comparative context of the European chemical industry, Darkow and von der Gracht (2013) found, using the Delphi approach, that sustainability and resource-dependency are the two main factors shaping the future of the industry [5,10, 38,42,51,66]. These factors also essentially contribute to the competitive advantages of the industry, in which rising pressures from environmental regulation and competition from Asia enhance the need for diver–sification of industrial business models [8,44]. Näyhä and Pesonen (2014) studied current forest industry change features required for a strategic shift towards a biorefining business in Scandinavia and North America using the Delphi approach [4,24,34,44]. Of increasing concern is that conflicts can arise over raw material prices, availability and sustainability act as barriers for changing the strategic focus in the capital-intensive forest industry [11,45,61,62]. Further obstacles for stra–tegic renewal towards sustainability are conservative organisational culture and limited financial resources as major hindrances for strategic renewal [3,26,46].

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 bioma–terials and biofuels, which are being defined as zero total carbon emission products [3,5].

5.1 Model for the European perspective

The European bioeconomy strategy focuses on: food security, natural resources, fossil fuel dependence and climate change [12,13,22]. However, when considering the fourth aspect of a sustainability model, social deve–

lopment, research and education policy, it has been observed that KBBE through the Framework Programme 7 (FP7) funding scheme, approved by the EU Council and Parliament, strongly influences national research budgets through setting in motion the European Research Area (ERA, e.g. KBBE-Net) [21,22,47]. However, EU policy has been criticised for policy which enables it to access patent rights from European participating companies, arising from research areas aligned with biotechnology [9,34]. Furthermore, critics claim that EU policies often use renewable eco-efficient terms synonymously with sustainable, which gives the impression that all renewable-sourced technologies bring lower air and water pollution and reduced waste [27,48,62]. This conflation assumes that biological resources can replace all synthetic chemicals, whilst organic waste automatically becomes a new resource, i.e. raw material for further productive processes, which are always assumed sustainable, since living nature is the abundant raw material source as it is inherently renewable, and therefore utilisation of waste is eco-efficient since it is not thrown away [41,50].

As an example, the EU (2013b) has, in its blueprint for forest-based industries, identified a total of 12 challenges. Those challenges emphasise 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 both within and outside the EU [44,50]. According to the European Commission (2013b), it is very important to build up business capable of meeting changing societal needs and improve the competitiveness of the forest sector. At the EU level, the Forest Sector Technology Platform (2015) has recognised new biomaterial-based products as an important research and development area for sustainability [12,36]. Also, national strategic roadmaps are defined with a strong emphasis on sustainability [46]. As the country with the largest wood biomass resources in Europe, Finland has established its 2030 roadmap for development in bioeconomy that will lead towards a carbon-neutral society where forest resources are seen as the source of bioenergy, aimed at substituting fossil fuel, while food demand is planned to be met by a self-sufficient society [14,51,52]. 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, as will be enlarged in a separate paper [31,35].

Key solutions and strategies that are to be implemented in the EU towards sustainable technologies within biotechnology must lead to a smooth transition and the long-term viability of a bioeconomy. To achieve this, a bioeconomy concept should include closed-loop recycling of all consumer products and materials, using a circular economy precept [51,53]. 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 [17,51]. For example, the Cascade circular economy is based on implementation of closed material loops in utilisation of available resources within larger loops, thus making continuous use of materials and then the wastes so long as products can be created [14,54]. This, however, requires highly sophisticated technologies and a high quality of biomass raw materials, excellent waste collection and sorting logistics regionally and internationally. Implementation of the circular bioeconomy strategies with the cascading concept is complex and requires detailed coordination between product designers and end-of-life materials managers, however the waste industry is still in an early stage [15,48-50]. In addition, for a sustainable use of biomass resources, the bioeconomy strategy (BMEL, 2014; European Commission, 2012) introduces a value-added oriented hierarchical utilisation of biomass for materials, chemicals, fuels and energy production only after they provide sufficient healthy supply of food and feed to meet the basic needs of society [34,51,54,55]. These precepts are schematically presented within the bio-based products hierarchy [3].

6. THE BIOMASS PYRAMID

European countries are becoming increasingly dependent on imported fossil energy. In the EU25, the demand for fuels is predicted to rise from about 50 EJ yr^{-1} (1 EJ = 1 exajoule = 10^{18} J) today to more than 70 EJ yr^{-1} in 2030, at the same time imported energy will increase from 50 % to 70 % [1,43]. At the same time need for land for food production will be increased by 50 % [28,43,60]. At the same time as increasing demand, Eurpoe needs to remain competetive on a global market and stay sustainable. For that reason the cascading principle of biomass distribution in the EU circular bioeconomy is depicted with the "Biomass value pyramid" (Fig. 4) [3,24]. The pyramid indicates priorities of use of biomass in the creation of bioproducts in the cascade circular economy; for example, the products made from waste from processes within the circular model bioeconomy stand lower in the pyramid, whereas pharmaceuticals gain priority sourcing and should be able to utilise high quality biomass [14,52]. As the pyramid grows higher, the processes become more complex and require more high-tech solutions, skills and knowledge [2,22]. As cascading is used to estimate the potential type and amount of materials that are available for the recycling infrastructures at a certain time, it also takes account of the quality of recycled materials in use-reuse streams, e.g. as outlined in European Commission, 2015 [9,45,48]. This is important for designing processes that utilise concepts of closed loops that can benefit from the highest value-added products with lowest energy consumption for the available resources [17,24,61].

Implementation of the circular economy and bio-economy strategies, employing the cascading concept, is complex and requires detailed coordination between product designers and end-of-life materials managers, i.e. the waste industry, and all are still in an early stage [25,31]. Key solutions and strategic actions towards a sustainable bio-economy should include closed-loop recycling of all consumer products and materials, using the circular economy concept [21], that keeps products and materials within the biomaterials pyramid [8,18], Fig. 4. 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. [44,50].

Demand for wood biomass for production of bio–fuels is especially high in European countries, as Euro–pe's lack of oil resources, following the decline of the UK [44,58]. North Sea reserves and the single depen–dency 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) [11,26]. That demand 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 [12,57]. South Korea, China, Japan, Brazil, Australia and India also appear to invest in production of biofuels [8,36]. To meet growing de–mands for wood, many countries look abroad to invest in land to secure vast ongoing supplies for the fast-developing biofuel industry [4,38].

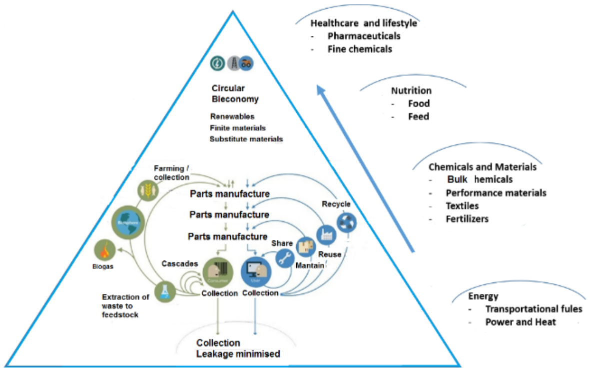

Fig. 4 Schematic illustration of closed loop concept of bioeconomy with cascading concept within the bio-mass values pyramid /adopted from refrencies / [3,14,24] /

Some researchers claim that wood biofuels are not sustainable in any form, not even as second-generation biofuels from waste arising from other biotechnology and food production as such activity is seen as a growing driver of deforestation and air pollution [25], [38]. While burning wood in balance releases less greenhouse gases, it releases more of some other pollu–tants, including fine particulates that are having nega–tive impact on health [28,58]. Meanwhile, there is extensive research demonstrating that carbon emissions measured at smokestacks from wood bioenergy facili–ties are up to 50 % greater even than for coal, as it needs more net energy to burn wood containing carbon, hydrogen, nitrogen and oxygen atoms whilst coal contains mainly only carbon and hydrogen, thus needing less energy input to breakdown molecules before combustion. When viewing further greenhouse gas emissions from fertilising land, logging and transportation, wood bioenergy is now being claimed to be among the *worst* renewable energy choices in terms of climate and environmental impact in comparison with energy created, say, from solar panels, wind and water flow, and, albeit increasingly less politically attractive, nuclear power [20,41,50]. There have also been documents published which claimed that conversion of agricultural land to wood culture for biofuel production led to increases in food prices, worsening emissions from fertilising land, land grabs and human rights abuses on a global scale [20,31,41]. What is additionally becoming increasingly clear is that different wood species require different processing conditions and design in biorefiners, for example, to avoid boiler corrosion problems [29,59].

A recent study detailed different scenarios of bio–mass 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 [49,58]. The growth analysis splits into 'low' and 'business-as-usual' bio–mass demand: the 'low' scenario assumes that other means of natural energy are developed for trans–portation (no biofuels), and covers the demand of bio–mass for food, i.e. only part of the demand for total biomaterials excluding bioenergy [4,45]. The 'business-as-usual' approach considers use of biofuels, requiring 18 billion tonnes of dry biomass, of which 5 billion tonnes is wood, covering the demand for food, feed, materials and bioenergy, with a modest utilisation of biofuels to up to 1 billion tonnes of dry matter of biomass [34,60]. When considering a defined 'sustai–nable' approach, only the 'low' biomass supply scenario can be regarded as keeping biodiversity at a similar level as today [34,59]. 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 impo–ssible to replace fossil fuels totally in a sustainable way, and more likely other sources of renewable energy must be developed [8,34].

7. THE FUTURE ROLE OF CELLULOSIC MATERIALS

In the light of the questionable role for biofuels discu–ssed 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 [18]. 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, Fig. 5, [17,54]. Implementation of cellulosic nanomaterials can in principle displace non-renewable materials with wide-ranging opportunities for nanocomposites with rene–wable minerals, such as calcium carbonate, in packaging, automobile manufacture, coatings, films, component housings etc. [61,62]. Panels could also use composites of cellulose nanomaterials to decrease car and aircraft weight and fuel consumption [64,65]. Due to high surface area, cellulosic nanomaterials in the form of porous aerogels and foams have already been used in absorbent products and designed for lightweight components, respectively, and this trend is expected to grow. It has been demonstrated that application of cel–lulosic nanomaterials drastically increases concrete fracture toughness at addition levels as small as 0.5 wt%, decreasing the need for non-renewable materials use [17,66]. Speciality markets for cellulose nanoma–terials already include flexible printed electronics and LED video screens, medical applications such as slow release drug delivery, incorporation in microfluid ana–lytical devices, aerogels preparations for bone and ,tissue scaffolding, and 3D printing [17,18,61].

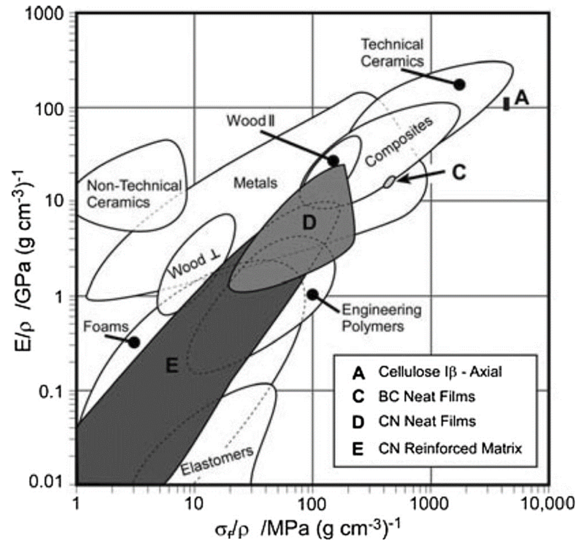

Fig. 5 Ashby plot of specific modulus (*E*/*ρ*) (stiffness) against specific strength (σ_F/ρ) for different products made of cellulose nanomaterials A-D, on a materials roadmap. Regions of crystalline cellulose (A), neat films (C, D), and reinforced matrix composites (E) are shown / Modified from referencies / [18,61] /

For successful use of biomass as a cellulose source, genetic modification of wood might be required to give cellulose fibres with increased crystalline to amorphous parts, lower lignin and hemicellulose amount, that will give higher yield in biorefineries [67]. However, as has been seen already, genetic modification of crops used for production of first generation biofuels has caused problems with cross fertilisation between genetically modified and non-modified crops, as it is impossible to control completely the circulation of pollen and seeds [12,68]. When considering maintenance of biodiversity for sustainable care of natural resources, there should, therefore, be ongoing carefully planned patterns of tree planting fulfilling the need for prioritising between primary and cultivated forests [63,69].

8. 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. 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 reaching this aim, more research, adopting methodology as used in, where both techno-economic and risk analysis on economic and environmental implications are included, needs to be undertaken. 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. The argument for the use of forest biomass is that it provides an alternative sustainable and unli–mited 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 cultural values evolution 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 deve–lopment in countries that the EU imports from or invests into, which directly influences the sustainability deve–lopment of the EU itself. Furthermore, an emphasis on bioeconomy alone has potential hazards concerning the omission of a reality-check of precise environmental impact, and it is vital that consideration of a fully cir–cular bioeconomy becomes the end target following any period of compromise management during transition.

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ИДЕНТИФИКАЦИЈА ИЗАЗОВА ЕВРОПСКЕ БИОЕКОНОМИЈЕ ЗАСНОВАНЕ НА ШУМСКИМ РЕСУРСИМ: РЕАЛНОСТ ЗАХТЕВА ЦИРКУЛАРНОСТИ

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Једна од најважнијих смерница Европске Уније је смањивање гасова који су узрок стварања ефекта „стаклене баште“. Истраживање природних заједница и екосистема захтева примену система циркуларне економије у коме би сировине природног порекла биле у константној циркулацији ка поновном коришћењу отпада. С тим у вези поставља се питање да ли биоекономија као једна од важних грана реално води ка заштит животне средине.

Питања која даље проистићу везана су за то да ли је пут ка биоекономији, који промовише Европска Унија заправо одржив. Коришћењем литературе, према Делфи методи, из докумената Европске Уније и научних публикација које су проистекле из истих, указујемо на значај одрживог управљања биоресурсима, јер делује да је само ограничено смањење емисија гасова са ефектом стаклене баште очекиване.