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Exploring 2040: Global Trends and International Policies Setting Frames for the Finnish Wood-Based Economy

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Abstract: Global trends influence the approaches and mindset for using natural resources and technological capacities. Participatory scenario methods have proven useful in long-term foresight. However, country-level foresight studies often ignore the broader trends affecting international markets and setting frames for economic development. This study envisions which global trends could occur and how the resulting European policies might affect the Finnish forest sector's development in 2040. We applied a Futures Wheel approach, where stakeholder groups consisting of policy-, economic- and social sustainability-, technology-, and climate sustainability -experts in the field of forestry and interlinking industries created three future scenarios in a workshop: (1) biodiversity and regulated economy, (2) circular economy, and (3) era of social connection. The scenarios assumed growing resource scarcity as a result of climate change, as well as over-consumption and increasing inequality problems globally. Thus, European-level policies focused on the circular economy and resource-use restrictions. Finnish industries should invest in wood-based side stream and waste utilization to increase added value and decrease virgin wood uses to succeed in these scenarios. However, this would require investments in non-wood energy sources to release these secondary wood flows from energy uses.

Keywords: futures wheel; Finnish forest sector; global trends; international markets; international policies

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Citation: Kunttu, J.; Wallius, V.; Kulvik, M.; Leskinen, P.; Lintunen, J.; Orfanidou, T.; Tuomasjukka, D. Exploring 2040: Global Trends and International Policies Setting Frames for the Finnish Wood-Based Economy. *Sustainability* **2022**, *14*, 9999. https://doi.org/10.3390/su14169999

Academic Editor: Piergiuseppe Morone

Received: 11 July 2022
Accepted: 8 August 2022
Published: 12 August 2022

1. Introduction

The European Commission identifies multiple megatrends that affect global future long-term development, including aggravating resource scarcity, climate change, environmental degradation, technological change, the expanding influence of the East and South, and increasing consumption [1]. Climate change is recognized as one of the biggest threats globally, with irreversible and large-scale impacts on the biophysical conditions of the planet and acting as an escalator for other threatening trends, e.g., biodiversity loss, social inequality and conflicts, and increased natural disasters. Simultaneously, global resource use has more than tripled between 1970 and 2017 [2] due to population growth and rising revenues. The annual resource consumption exceeded 100 billion tons per year globally in 2020 [3], despite the COVID-19 pandemic. The OECD (2019) estimates resource consumption at 167 billion tons in 2060 if new restrictions are not adopted. In 2018, the Intergovernmental Panel on Climate Change stated that fast, wide-ranging, and unprecedented changes in society are required if we are to limit global warming to 1.5 degrees Celsius and prevent these hazardous side effects [4]. In 2022, the IPCC raised the urgency of action again [5].

The future of any international field of business is affected by each of the planet-wide current, as well as by trends still unknown to us. Despite political efforts to reduce the utilization of fossil fuels, their share in the energy mix of the final energy demand globally was still 80.2% in 2019, which is only marginally less than in 2009 (80.3%) [6]. Individual industrial sectors are making efforts and long-term strategies to transform their business models and make production more sustainable. However, sectoral development and other market development studies often focus on narrowed question settings and do not consider the circumstances of humankind, thus potentially failing to see the change in the total market environment and feasible solutions. The same applies to wide international policies, which have the potential to lead to unforeseen negative impacts, e.g., inequality problems and possibly resulting in conflicts, when failing to consider risks in the prevailing future circumstances.

Renewable resources, including forests, have multiple roles in sustainable transition strategies. The demand for bio-based products substituting fossil energy and fossil-derived products has soared in industries such as construction, packaging, textiles, plastics, and chemicals. However, tapping on, per definitionem, of green forests has become a controversial issue that reflects rapidly growing political fervour colliding with significant economic interests. Forest utilization is under political debate since forests act as important carbon sinks that sequestrate and store carbon in the ecosystem, as well as provide billions of species their living environments, and act as critical erosion preventers and micro weather balancers. They provide a wide range of ecosystem services and (potentially further extended) material and energy applications. Consequently, optimizing the use of forests depends on the goals and priorities set for forests in a given time frame, geo-demographic conditions, and alternatives available to contribute to climate change mitigation and offer substitutes. The utilization patterns are constrained by capacity, too, which can be threatened due to climate change [5].

Effective long-term strategies are even more difficult to form on a country level since the economic capabilities greatly rely on the international policy environment and markets. In Finland, our case study country, forest lands are 86% of the land use and are a significant natural resource in volume, and the national strategy for sustainable transition heavily relies on them [7]. The Finnish forest sector contributes around 19% of the total value of export in goods, and wood-based production employed, in total, nearly 74,000 persons (about 3% of the employed) in 2018 [8]. Thus, economically, forests and their utilization have a major impact on the whole economy in Finland. Foresight methods, such as scenario techniques, are suitable for exploring potential long-term structural changes in wood-based markets as well as their consequences [9]. The diversification of wood-based products has been studied by applying these methods in, e.g., studies by Hagemann et al. (2016) [10] and Hurmekoski et al. (2018a) [11]. Generally, wood-based product markets are expected to renew, and new and emerging wood-based applications, such as wood-based composites, textiles, and chemicals, are expected to increase their market shares when the policy priority is to substitute non-renewable applications [11]. However, there is a knowledge gap regarding individual countries' sectoral development reflecting on general global scenarios, which expose the wider market environment and difficulties humankind may face in the future. In Europe, four types of scenario approaches have emerged over the last decade: management scenarios, environmental scenarios, optimization scenarios, and participatory scenarios [12]. According to Hoogstra-Klein et al., 2015 [12], despite the benefits of participatory scenario development, only a small number of participatory studies appear to be participatory in nature [13,14].

The aim of this study is to explore the development of the Finnish economy and forest sector under the possible global changes and their reflection on the European policy environment and the markets. The study was performed by applying a Futures Wheel [15] participatory scenario technique. The study seeks to explore (i) likely major global trends most affecting humankind in 2040; (ii) consequential European policies and R&D funding priorities, as well as the general market environment; and finally, (iii) the causal impacts on the development of the Finnish forest-based economy, in this order. A quantitative illustration method, showing the structure of wood-based portfolios under each scenario, is applied to the participatory scenario development process to identify the magnitude of change in the Finnish wood-based portfolio structures.

2. Materials and Methods

2.1. Scenario-Building Overview

This study utilizes a scenario approach similar to the Futures Wheel, originally developed by Glenn (1972) [16]. The Futures Wheel is a participatory approach where a group of stakeholders builds a scenario in a workshop to a wheel-like form, starting from a centre trend and expanding the scenario consequence by consequence. In the original method, the centre trend is predefined, and participants are selected afterwards [15,17]. The centre trend is typically the main topic of the study. This can be any significant change in the future, e.g., new policy or living conditions [17]. The idea is that participants start brainstorming first-order consequences of the centre trend, positive or negative, and then second-order consequences based on those outcomes. After reaching the point of 'third-order consequences', the Futures Wheel is typically considered detailed enough [17].

In this study, the centre trend was not predefined; instead, stakeholder groups created their own centre trends describing the major trends affecting human life globally in 2040. The main question, 'how may the Finnish wood-based economy look like in 2040', was focused on the last phase of the process. Our aim was to avoid narrow thinking, e.g., Finnish wood utilization patterns would develop independently from the global environment—an imminent risk if the forest sector had been predefined as the central theme. In other words, the relevant question was how the major future trends and international market forces might affect the Finnish forest sector's development, rather than how the Finnish forest sector affects international markets. Thus, the Futures Wheel approach was modified to focus on three geographic levels (global, European, and Finnish) (Figure 1). However, only Finnish-level questions were specific, whereas global- and European-level questions were more general (see Supplementary Material S1).

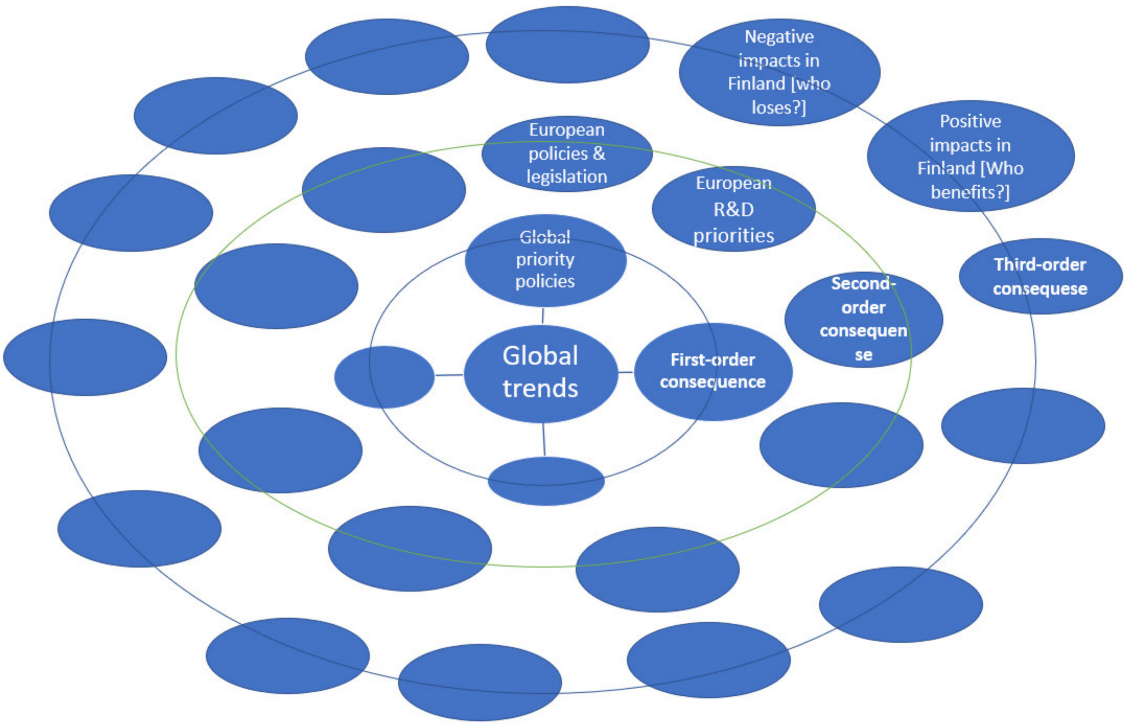

Figure 1. A chart representing the form of applied Futures Wheel (Glenn, 2009) in the study at hand.

The first-order consequences implied the global main policy priorities, affected by the central trends, which were the most likely conditions affecting humankind globally according to stakeholders. The second-order consequences were the highest-consequence impacts at the European level stemming from global trends and policy priorities. The third-order consequences were the consequent impacts on Finland, specifically on the Finnish forest sector. Finally, the stakeholders gave numerical estimations of their expression of the Finnish wood-based product portfolios under the scenarios. The workshop steps are presented in more detail in Section 2.3, 'Workshop'.

2.2. Selection of Stakeholders

Typically, in the Futures Wheel method, the stakeholders are selected based on the predefined centre trend [15], which is typically the main question of the study. In this study, however, the main question setting was in the third-order consequence phase (Finnish wood-based sector development), and the stakeholders were selected accordingly from Finland but with international expertise. In participatory methods, it is crucial to ensure the stakeholders represent diverse backgrounds [18]. Based on previous studies, the main factors affecting wood-based bioeconomy development are (i) international and national legislation and regulation, (ii) research and development efforts, and (iii) competitiveness of fossil-fuel-derived products or cooperation between different industrial fields and research sectors [10,19,20]. As the knowledge of international circumstances was considered generally important as well, we specially selected stakeholders whose expertise background (implemented research or work at the industries/political institution/interest group) included international aspects. Thus, we recruited workshop participants from the following topical fields of expertise: policy, economic, and social sustainability within value chains; technology; and climate sustainability in the field of forestry and interlinking industries (energy and plastics industry). We included researchers (Ph.D. or equivalent expertise at least) as well as industrial actors (managerial position at least) and interest groups (managerial position at, e.g., associations). As we recognized that the age distribution was skewed toward participants over 30 years old, more variety was gained by recruiting two students under 30 years. The coverage of experts was considered sufficient for the workshop when there was at least one stakeholder from each field of expertise and at least one from each 'participant category' (see Table 1).

Table 1. Stakeholder matrix, where the value represents the number of stakeholders in a specific cell (topical background and type of stakeholder).

Topical Background	Researcher (at Least Ph.D. or Equivalent)	Young Expert (Student under 30 Years Old)	Industrial Actor (Managerial Position)	Other Expert (Interest Group, Managerial Position)
Policy	1			1
Forest economy/Economy general	1	1		
Value chain sustainability (in general inc. economic, social, and environmental aspects)	1			
Forest technology	1		1	
Climate sustainability	1			
Wood-based new/emerging products			1	1
Energy sector		1		1
Plastic industry				1
Total participants (13)	5	2	2	4

2.3. Workshop

The explorative scenario development was implemented as a half-day workshop on 19 December 2019. The participants were divided into three groups, with four participants in two groups and five in one group. The aim was for each group to develop a consistent scenario, finally describing the Finnish wood-based economy in 2040 and the conditions explaining the changes.

The workshop was implemented in five steps: (I) the introduction of the scope and future-oriented mind setting, (II) expected global main trend development in general,

(III) implications for main global trends at the European level (European policies and Research & Development funding priorities), (IV) consequences in Finland (general market environment in Finland and specific attention to wood-based sector), and (V) quantitative illustrations of wood-based product portfolio development and forest harvest levels. The questions created the scenario pathways that were afterwards transcribed into scenario stories. The questions guiding the workshop in the different geographical levels were: 'What are the most likely main trends affecting humankind in 2040 globally?' and 'what are the 1–3 global policy priorities based on issues that raised in the trend invention?' (global level), 'what kind of policies, strategies and legislation could take place in the European level, when considering the formed global trends and policy priorities?', and similarly, 'what could be the public funding priorities?' (European level), and finally, 'what the market environment in Finland could be and which sectors/industries the European level policies and funding priorities affect the most in a positive or a negative way' and 'how the development of forest-based sector is affected under the scenario circumstances and what kind of forest utilization practices take place and are favoured/not favoured' (national level). The groups were also asked to freely discuss the following points: 'What is the position of wood-based energy and how the traditional wood-based products succeed in these markets?', 'what new forest-based products, -innovations and -services are introduced and increase their importance in markets?', and 'how the harvest level could change compared to today's level?' The main points of this discussion were written down as notes by the staff, 'observer'. The aim of this exercise was to prepare the group for the final phase of the workshop, numerical illustrations.

The quantitative illustration was an anonymous individual task by each participant in the scenario groups. The quantitative illustrations were given as an allocation share of total Finnish wood flows to intermediate product categories: heat and power (direct energy use), liquid biofuels, biochemicals, dissolving and chemical pulp, mechanical pulp, sawnwood products, wood panels and cross-laminated timber (CLT), and wood-based composites and hybrids. The stakeholders were also asked to rate the Finnish harvest level compared to today's level (increase or decrease in percentages). The detailed setup, structure, and questions of the workshop are presented in Supplementary Material S1.

To prevent any individual stakeholder from dominating the scenario pathway formation and to assign equal weight to each participant's contribution, we used the Ketso workshop toolkit and philosophy [21] developed by Dr. Tippet. The idea of the Ketso is that individual participants can write their opinions down to be included in scenario pathways one by one so that everyone has the opportunity to express their opinion, and no opinion is more/less important than another. This makes the process transparent and allows participants to utilize each other's ideas, and thus be more creative [22]. The Ketso toolkit also enabled the staff of the workshop to organize the invented consequences by their theme (e.g., circular-economy-related consequences placed in the sheet closely together). This feature helps to identify topical themes in the transcription phase (see Section 2.4).

2.4. Compiling the Workshop Data into Scenario Pathways

The scenarios were transcribed into scenario pathways (stories) first in MS Excel tables. Since invented scenario features were already structured in the Ketso sheets so that the consequences in the same topical theme were clustered more closely together, extraction to Excel was more efficient. The different themes included, e.g., circular economy, energy generation, water and food, and different wood-based industries, such as forest-based chemistry. In each scenario-formation group in the workshop, there also was an external staff member who made notes of the stakeholder conversations. This was to prevent any misunderstanding if a written consequence was in any way unclear in the transcription phase. Full scenario descriptions were formed based on the original question and invented scenario features. The quantitative illustrations were created by taking the arithmetic average of the responses regarding harvest level and product group allocation within each group and dividing it by the number of participants in the group (scenario). The extracted results and quantitative illustrations are presented in Supplementary Materials.

3. Results

3.1. International Common Trends and Phenomena in the Scenarios

Three different scenarios were created in the workshop. The scenario attributes are completely based on stakeholder input. The stakeholders invented the attributes based on what they consider likely events or likely consequences. In global pathways, the stakeholders assumed hazardous weather phenomena, drought, and reduced living space resulting from climate change in all three scenarios. Common trends also included decreased food and water availability, as well as increased migration. In the global markets, stakeholders assumed a dominant position for China. Food and water security were assumed to be a global policy priority. The alternative clean energy technologies, replacement of fossil fuels, and carbon capture and utilization were assumed to take big leaps, but the level of development varied between the scenarios. For example, in one scenario, it was assumed that renewable energy sources and nuclear energy had replaced fossil energy completely by 2040, whereas, in others, this development process was still ongoing. Concern for social conflicts and war was present in all scenarios.

3.2. Global General Trends and European Priorities in Policy Actions and R&D Funding Themes

This section describes the general, major trends affecting humankind globally, as well as European policy actions and R&D funding priorities under each scenario:

- 'BD-REGU': 'Biodiversity and Regulated Economy';
- 'Circular Economy: A way to sustain abundant lifestyle?';
- 'CONNECT': 'Era of Social Connection'.

3.2.1. Scenario 'BD-REGU': 'Biodiversity and Regulated Economy'

In the 'BD-REGU' scenario, the living conditions are difficult globally because climate change has advanced to a point where it increasingly causes hazardous weather phenomena and drought. Recurring drought has negative effects on global food production and water availability. The shortage of food and raw material resources escalates in vulnerable areas, and social and economic inequality increases. Stakeholders assumed that wars over resources might arise, and humanitarian crises might become common. China was assumed to hold a dominant position from economic and military perspectives in this scenario. The indirect impacts of climate change are likely to lead to less living space and migration with high numbers of climate refugees. Generally, social insecurity and different kinds of uncontrolled crises affecting humankind are common. Social inequality is exacerbated, with majorities suffering from a lack of goods and services while other rich minorities consume more than necessary. Efforts are made to replace fossil fuels completely, while carbon tax and carbon capture technologies are adopted. However, the commercialization of carbon-capture technology has taken big leaps, with, e.g., carbohydrates being produced from carbon dioxide.

Based on the above scenario conditions, global priority agreements were assumed to be the '*pricing of external impacts of consumption and production*' and '*water agreement*'. Stakeholders determined that without creating a political system that also supports the weakest groups, income inequalities and wide differences in living standards would lead to a collapse in this scenario. Thus, external impacts of consumption would be included in product prices. Stakeholders evaluated that moving into a regulatory (command/planned) economy would be difficult in general because, in the long-term, individuals' own initiative, motivation, and decision-making power should not be taken away, and individuals should be rewarded for trying and thereby producing solutions. To prevent global conflicts, income distribution to developing countries for administration, education, etc., was considered possible, but this might be an action only taken by certain countries and is not a globally agreed-upon goal.

Stakeholders assumed that countries in Europe had made water trade agreements in line with global agreements. However, stakeholders did not assume the pricing of external impacts of consumption at the European level. Instead, the aim would be to enhance sustainability by using more direct regulation, e.g., restrictions on forest uses. Restrictions on forest utilization would be pinned to new directives driven by biodiversity objectives. Hence, biodiversity receives more attention, and this leads to new forest-management practices where carbon balance and biodiversity come first. Carbon trade is also applied at the European level, at least. Additionally, a circular economy becomes apparent in political decisions, and restrictions on the use of virgin raw materials are agreed upon.

Stakeholders assumed that wood would not be automatically considered carbon neutral in this scenario, e.g., restrictions are introduced for wood-based fuel utilization (but not production). However, stakeholders assumed that wood-based construction and hygiene products would be accepted as carbon neutral by both the regulation and the public. In general, biomaterial production and its use are boosted through policy instruments and, if implemented through production subsidies, will be volume-based. Technologies adapt the principles of the circular economy. Detailed requirements are introduced for the best available technique utilization. As biomaterials in production and utilization are heavily focused on material production and not energy, the prioritized energy sources focus on other solutions, e.g., nuclear energy. At the same time, high (carbon) taxation is applied on fossil fuels and incentives for the electrification of motor vehicles.

In Europe, the R&D funding themes focus on the sustainable use of resources, such as water technology development and plant breeding. Biomass-related research focuses on the sustainability of material production and processing, including wood-based production. In energy technologies, research focuses on flexible nuclear power solutions and fusion. Circular economy concepts are likely to appear in research in all scientific fields, and instead of only focusing on part of the value chains or only at the European level, the aim is to optimize and develop sustainability of the global value chains, including their carbon footprints. This indicates that efforts are made to avoid 'carbon leakage' and pay attention to carbon balances globally. Research on artificial carbon sinks also takes place. Circular economy solutions in Central and Southern Europe receive attention as well, and, as a concept, the improvement of 'development cooperation and expertise' will be a research theme itself. Since biodiversity is a concern, the development of biotopes is also highlighted.

3.2.2. Scenario 'CIRCULAR': 'Circular Economy: A Way to Sustain Abundant Lifestyle?'

CIRCULAR is like the other scenarios in that climate change causes more migration as well as natural disasters and catastrophes. The availability of clean water is a major issue, and increasing drought harms further agricultural activity, leading to the increasing abandonment of rural areas. This catalysts food shortage, and people are increasingly centralized in megacities with less living space. However, generally, life expectancy is high, including in far East countries, and as birth rates are globally low, the population is ageing. It was assumed that in this scenario, renewables and nuclear power might have already replaced fossil fuels. Digitalization would have enabled higher energy efficiency. Therefore, consumption still increases, and an abundant lifestyle is common. Digitalization shapes markets in multiple ways by affecting both production and consumption patterns.

The globally agreed number one political priority is to *develop and secure food production and availability*. Secondly, the goal is to *develop energy systems*. The stakeholders assumed that a successful shift from fossil fuels to clean energy sources requires continuous efforts in R&D, especially as the consumption of goods is still increasing.

As the development of food production is the main priority globally, at the European level, it leads to open and permissive genetic modification (GM) legislation. In addition, investments are made in developing countries to avoid migration and the centripetal movement of population, as well as to promote ruralization. Incentives for renewable energy are used to boost forms of clean energy, or emission quotas are alternatively used.

GHG emission reductions achieved elsewhere globally are allowed to count toward the national commitments (currently known as Article 6 of the Paris Agreement), high carbon tariffs are adopted, and there is still a commitment to carbon neutrality by 2050. Naturally, biomass plays an important role in production since fossil-fuel-based production systems are still being replaced. To achieve this, strong incentives are adopted to increase the use of biomass and renewables in production. At the same time, the increasing consumption trend focuses attention on natural resource limits. Thus, circular economy policies take a stronger position, and the over-utilization of virgin resources is financially sanctioned. European waste legislation is strict overall, and there is a prominent recycling obligation, including for consumer waste. However, material recycling is not automatically considered a better option than its utilization for energy. As replacing fossil fuels in energy generation occupies a large share of bio-based resources, material vs. energy optimization is required.

The material/energy optimization is also shown in prioritized R&D themes at the European level. Value chain optimization is included in the themes, as are more efficient recycling techniques, such as chemical recycling and the chemical separation of materials. Biochemistry, in general, receives a lot of attention in funding themes (e.g., enzyme utilization in material production) along with biomedicine. At the same time, scaling new materials into production is supported. The annual funding for circular economy enhancement themes is binned to a certain share of GDP. The same applies to energy system development themes, which highlight, e.g., hydrogen utilization ($H + CO_2$), self-sustaining microgrid development, and energy forests in tropical areas. Important themes in R&D also include artificial-food-production technology solutions, especially in 'primitive' conditions.

3.2.3. Scenario 'CONNECT': 'Era of Social Connection'

In the 'CONNECT' scenario, the global conditions related to climate change are the same as in other scenarios. The population is ageing, especially in the Western countries, but elsewhere too (e.g., in China). Climate change causes increasing migration (e.g., because of rising sea levels), and the consequences could pose a global threat of war. However, this scenario is more advanced compared to other scenarios in terms of digitalization and energy technologies. Artificial intelligence and robots are part of everyday life, improving, e.g., the safety of production processes. Tourism, particularly virtual tourism, is common, and business connections are expanding. One of the most significant differences between this scenario and the others is a globally visible cultural shift. Social relationships, family, and friends have a high priority over work. In other words, 'performance society' is history. Additionally, a non-materialistic lifestyle is a major trend. The stakeholders believed that the next generation is more aware of the global situation from an early age and, as a result, begins to invest in cooperation rather than selfishness. Because of this mindset, global problem-solving is more efficient; for example, clean energy technologies have already replaced fossil fuels, and the global waste problem is being addressed with circular economy tools. Carbon-capture technologies and hydrogen fuels are widely in use.

Because population growth is assumed to continue in this scenario, the first globally agreed-upon policy priority was to *impose restrictions on consumption and resource use (less is more)*. Second is *ensuring universal access to food and water*, and third is *increasing global carbon neutrality investments*.

At the European level, the pricing of the external impacts of consumption is based on a taxation set for extra-consumption (consumer pays) and production (producer pays). This means that the economy is being regulated. On the other hand, trade is less regulated (free trade promotion) to prevent global conflicts. For example, carbon tariffs are missing in contrast to the other scenarios. Incentives are directed toward carbon-capture technologies to ensure carbon neutrality while landfilling is completely banned. Public investments are made to promote positive social impacts, and social criticism is accepted. Europe has also made more community agreements on a smaller scale than the EU, where cooperation between countries in, e.g., trade or R&D is improved. European aid policies have also been renewed, emphasizing the utilization of the diverse skills of community member countries (targeting support for diversity). Another high political priority is the ecology of living areas. Incentives are used to ensure that 80 per cent of the living areas are blue or green. Incentives are also being directed toward digitalization in all living areas, specifically in the form of 'smart built environments', but also more broadly. Renewable energy must provide 100 per cent of household energy, which can be accomplished through incentives or restrictions.

In the prioritized R&D themes at the European level, energy self-sufficiency with clean energy forms and renewable energy sources is one of the main interests of the circular economy and material resource efficiency enhancement. Funding is allocated to, e.g., waste recovery and reuse, product repairing, and extending the product lifetime. One development theme is 'intelligent materials' in buildings. In line with the new 'non-materialistic lifestyle', funding is directed to a new research priority theme: non-material production and consumption. Biodiversity also shows in funding themes. Along with investing in social impacts, wellbeing and mental health are two of the cross-cutting themes in R&D. This is connected to, e.g., water- and food-availability-development-boosting ruralization. This way, the population can be directed to rural areas.

3.3. Scenario Pathways for the Finnish Economy in General and the Finnish Forest Sector

3.3.1. The Current Status of the Finnish Forest Sector

The total amount of harvested roundwood was 69 million cubic metres in 2020, while in 2019—pre-COVID—it was 73 million cubic metres [23]. According to the National Forest Inventory (NFI) 13/12 (2016–2020), the total annual growth of Finnish forests was 103.5 million cubic metres in 2020 [23]. Nearly half of the wood flows ends up as industrial side streams, e.g., bark, sawdust, wood chips, and black liquor [24,25]. Since the side streams are mostly used for energy, in the total product group allocation of wood, the energy use accounts for around one-half (Figure 2). Sawnwood production accounts for 23%, chemical and dissolving pulp account for 15%, and mechanical and semi-chemical pulp account for 10% (Figure 2). The wood panel production covers only 2% of the product portfolio of total wood allocation. Biochemicals, biorefinery, liquid fuels, and packaging, as well as wood and wood-based composites, have a 0% share due to their marginal contribution to total production.

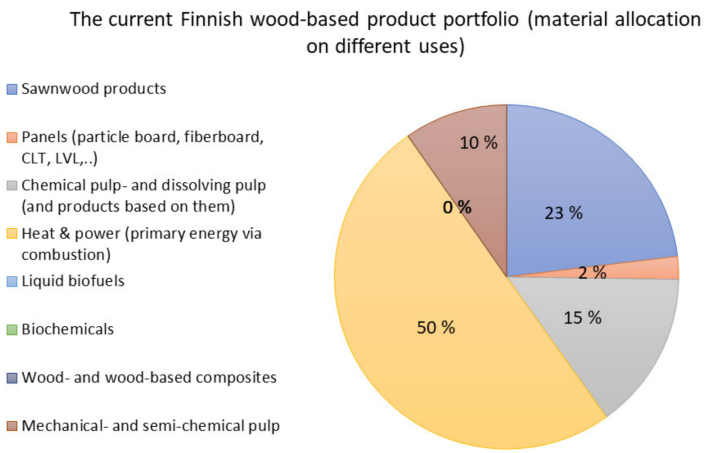

Figure 2. The Finnish wood product portfolio presented as wood flow allocation on intermediate product groups based on 2017–2019 data. The total production accounts for wood-based material flows (including flows from Finnish forest and side streams from the industries). Data for the figure from Kunttu, 2021 [25].

3.3.2. Finland under 'BD-REGU': 'Biodiversity and Regulated Economy'

The stakeholders determined that the producers of renewable energy, such as solar, wind, and hydropower, benefit from energy technology advancement and renewable energy promotion in Finland. Fossil-fuel-based sectors and companies and linear-economy-based producers would suffer financial losses. According to the stakeholders, only businesses that can completely reinvent themselves would thrive, given that their production is centred on innovative biomaterial solutions such as textiles and, in particular, chemicals. The distinction between chemistry and the forest industry would be blurred, and it would be possible to refer to forest industries as 'forest chemistry industries'. Start-ups that develop innovative technologies and sustainable value chains would succeed as well. Stakeholders predicted that public payments for supporting biodiversity and expanding protected areas would be extremely high. Forest owners and landowners could benefit financially because of the pricing of biodiversity and possibly resulting stem value increases. The harvest level was assumed to increase by 43% in 2040 compared to the current harvest level.

Figure 3 presents the Finnish wood-based product portfolio visualization in BD-REGU in the year 2040. The sawnwood products and chemical and dissolving pulp have the highest representativeness in the product portfolio. When panels and CLT are accounted for, they represent 52% of the total Finnish wood-based production altogether. The direct heat and power production is only 13%. In this scenario, it was highlighted that wood is too valuable to be combusted; it should only be the last end-of-life option. Liquid biofuels represent 14% in the portfolio, and biochemicals represent 10%.

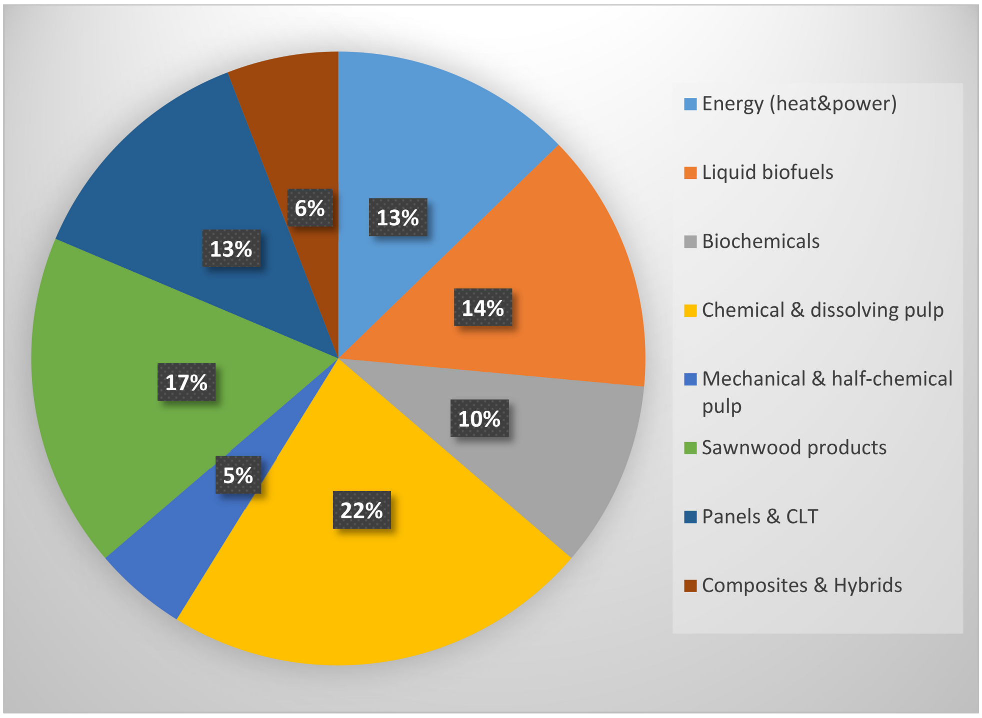

Figure 3. The Finnish wood-product portfolio in BD-REGU presented as wood flow allocation for intermediate product groups in 2040. The flows account for wood-based material flows (including flows from Finnish forest, side streams, and end-of-life waste wood) and allocation to different intermediate product groups based on stakeholders' numerical visualizations.

3.3.3. Finland under 'CIRCULAR': 'Circular Economy: A Way to Sustain Abundant Lifestyle?'

According to the stakeholders, the industries producing non-recyclable materials would suffer in the CIRCULAR scenario. Bulk-product industries were assumed to suffer financially, as well as fossil-fuel-mining industries. Agricultural areas might also suffer from drought. In general, the export of 'know-how' and education was considered to increase. The biochemical industry, especially related to enzymes, as well as the combined forestry–chemical industry, was assumed to be successful due to major R&D efforts. Generally, all renewable-based industries would benefit because of the political efforts to replace fossil fuels. Thus, especially clean-tech solutions, as well as digital technology development companies, would have a chance to grow rapidly. Digitalization and new energy technologies boost the service sector, too, especially tourism. Digitalization growth may save virgin resources due to resource efficiency. Stakeholders evaluated the harvest level to grow 7.5% compared to today's level.

The primary energy use of wood was assumed to be relatively low (10%) in the wood-based product portfolio (scenario visualization, Figure 4). The representativeness of liquid biofuel production is 12% and biochemicals 8%, respectively. Chemical and dissolving pulp was assumed to have the largest share in the product portfolio (23%), followed by mechanical and half-chemical pulp production (14%). Traditional sawnwood products represent 11%. Panels and CLT, and composites and hybrids, also both have 11% representativeness.

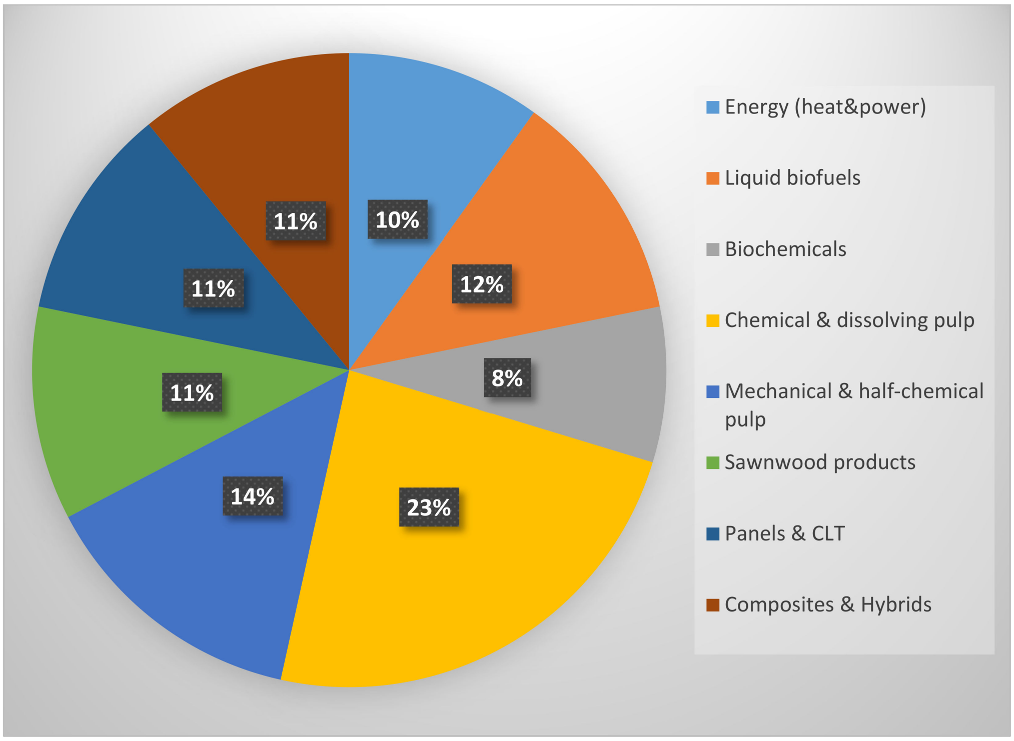

Figure 4. The Finnish wood-product portfolio in CIRCULAR presented as wood flow allocation on intermediate product groups in 2040. The flows account for wood-based material flows (including flows from Finnish forests, side streams, and end-of-life waste wood) and allocation to different intermediate product groups based on stakeholders' numerical visualizations.

3.3.4. Finland under 'CONNECT': 'Era of Social Connection'

The stakeholders evaluated that in CONNECT, a cultural change can also be seen in Finland, meaning that social relationships are more important than work. Thus, wellbeing and happiness increase, and children especially benefit. Because the non-materialistic way of life is an increasing trend, the biggest winners would be the service and information technology sectors. In the service sector, tourism and nature services and art-based businesses succeed. From the professional perspective, technological engineers are especially needed. However, the stakeholders considered it possible that employment is more fragmented and that most of the employees are working under employment agencies. In the energy sector, renewable-based industries dominate the local markets. In this scenario, all fossil-fuel-based production is deemed unprofitable. The European 'green infrastructure' requirements may enable the afforestation of treeless areas and in cities, which increases CO_2 uptake. Municipalities may face financial difficulties when attempting to update infrastructures to meet political requirements. In general, the stakeholders stated that it is completely up to the forest sector itself whether it will be successful in this scenario or not. Only those business concepts that are able to renew 100% can survive. If the structural change is successful, the value of export (incl. services and technologies) could increase drastically. While mental wellbeing increases due to cultural change, it is also possible that Finnish GDP decreases if the old business models and attitudes stay. According to the stakeholders, forest owners would still likely benefit from this scenario, as there would be more possibilities for forest utilization, which affects the land value, too. The harvest level was assumed to increase 24% on average compared to the present.

In the scenario visualization, heat and power production represent only 5% of the Finnish wood-based product portfolio (Figure 5). The primary wood industries (sawmilling and chemical and dissolving pulp industries) have equal shares in the product portfolio (18%). Mechanical and half-chemical pulp represents 13% of the product portfolio, wood-based biochemicals represent 9%, and liquid biofuels represent 16%.

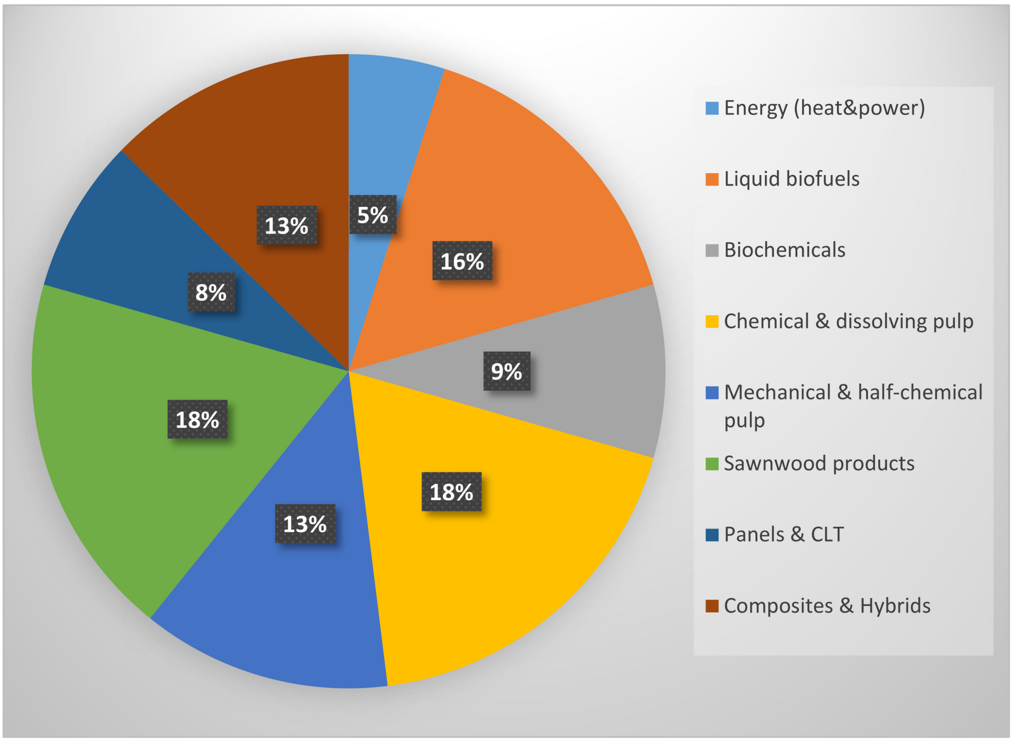

Figure 5. The Finnish wood-product portfolio in CONNECT presented as wood flow allocation to intermediate product groups in 2040. The flows account for Finnish wood-based material flows (including flows from forests, side streams, and end-of-life waste wood) and allocation to different intermediate product groups based on stakeholders' numerical visualizations.

4. Discussion

4.1. Overview of the Study Aims and Scenario Pathways

The aim of this study was to exploratively create scenarios for Finnish forest sector development in 2040 that also take a broader perspective on global circumstances creating the frames for international markets and policies affecting the country-level development. Scenario pathways created in the workshop narrowed from broad global trends affecting the whole of humankind and international markets to more detailed European policies, and finally to the market circumstances and structure of the wood-based sector in Finland. The application of the Futures Wheel (Glenn 2009), a participatory scenario technique, was used. The workshop participants formed three different future scenarios, where scenario BD-REGU ('Biodiversity and regulated economy') called for strict political actions to enhance biodiversity and restrict forest harvesting and certain production patterns; CIRCULAR ('Circular economy: A way to sustain abundant lifestyle?') introduced obligations to improve material circulation and reduce natural resource utilization; and CONNECT

('Era of social connection') highlighted cultural change, free trade, social wellbeing, green infrastructure, and digital solutions to enhance ecological sustainability. CONNECT was clearly the most advanced in terms of technology development, versatile energy generation solutions, and decreased consumption and global efforts for social well-being.

All three scenarios shared dark global trends, including natural disasters, scarcity of resources, and the increasing threat of conflicts. This could be a result of general consensus in the research field on the impacts of climate change. The stakeholders were generally highly educated, which has likely influenced their future visions. However, envisioned political reactions and market environments stemming from those circumstances varied. Some recurring trends were implied in all three scenarios: at the European level, a circular economy, clean water technologies, plant breeding, and GMO development show up strongest in policy-making as well as in R&D&I funding themes throughout the scenarios since food and water availability was a global risk. Secondly, developing clean energy sources and technologies was highly ranked in all scenarios, as well as biomaterial use in production processes. Due to increased immigration, demand for food production, and decreased living space, CIRCULAR and CONNECT also focused on enhancing ruralization. Carbon balance optimization was considered in all scenarios, aiming to decrease emissions within value chains. The scenario differences are discussed in more detail in the next Section 4.2.

4.2. Differences in International Policies and Impacts on Finnish Wood-Based Production

The European policies in the BD-REGU scenario were highly focused on GHG emission reduction while considering global value chains and biodiversity. Here, the stakeholders assumed new biodiversity-based restrictions (EU directives) on forest utilization, incl. harvesting. In addition, wood utilization was not considered automatically carbon neutral, and only some products, such as wood-based construction and hygiene products, were accepted by the policies and the public. Under this scenario, stakeholders assumed restrictions for wood-based biofuel use. Some indications of possible restrictions regarding woody biomass utilization for energy already exist. For instance, a draft for the new Renewable Energy Directive (REDIII) highlights the importance of avoiding unsustainable biomass utilization [23]. It states that 'woody biomass should be used according to its highest economic and environmental added value in the following order of priorities: (1) wood-based products, (2) extending their service life, (3) re-use, (4) recycling, (5) bio-energy and (6) disposal', which also implies more circular economy practices [26]. Compared to BD-REGU, CIRCULAR might offer a more flexible system for Finland since the energy use of secondary wood flows remains an accepted approach. Currently, over 50% of the total wood flows (incl. side streams and waste wood) are used for energy-generation purposes in Finland [25]. According to the report of ÅF Pöyry (2020) [27], in the Finnish low-carbon scenario, the utilization of wood-based fuels in combined heat and power generation increases by 11 TWh from 2017 to 2035 and reaches 89 TWh in 2050. In general, in these scenarios, electricity relies heavily on renewable sources such as solar, wind, and hydrogen power. According to estimates, there is the capacity to increase wind and solar power facilities in the future in Finland if the transition is made economically profitable [28,29]. However, it is much more difficult to replace industrial mill energy with energy sources other than wood. Thus, BD-REGU creates a risk for Finland's energy self-sufficiency. On the other hand, increasingly covering the mill energy needs with industrial wood-based side streams could hinder the expansion of the wood-based product portfolio. This is because side streams have the potential to be used for various high-added-value products [30].

In scenarios other than BD-REGU, wood-based raw materials were politically regarded as a subsidized solution in both material and energy production. The circular economy efforts were overall clearly the highest in CIRCULAR, which introduced strict waste legislation and an obligation percentage for recycling. A share of GDP would be used to enhance circular economy development and value chain optimization. Carbon neutrality was a set demand for all production, and the over-consumption of virgin resources would still lead to financial sanctions. The utilization of recycled materials and recycling technologies in, e.g., textile production, can also increase energy savings, thus contributing to emission reductions [31]. However, the technology development and required logistical value chains around recycling require high investments [32], which may, at least for some time, hinder the cost competitiveness. However, since financial support was assumed to be directed for these activities, recycling technologies may become profitable in a sufficient time.

In CIRCULAR, Article 6 of the Paris Agreement would be adopted (allowing emission reductions achieved elsewhere to count toward the national commitment). It is argued that carbon credits and trading could help with more rapid development toward net-zero emissions, but only if the over-counting of emission reduction was avoided and if the emission reductions could be verified and accurately accounted for [33]. Still, compared to other scenarios, CIRCULAR clearly encouraged the highest production of innovative bio-based products, such as biochemicals and biomedicines, to the markets through incentives. In CIRCULAR, high carbon tariffs were also assumed to be adopted at the European level. Böhringer et al. (2018) [34] state that carbon tariffs can indeed decrease the carbon emissions of goods produced outside the EU, but at the same time, this could increase the costs of emission reduction globally. This could potentially further contribute to inequality problems between countries. Nevertheless, the modelling study of Fang et al. (2020) [35] suggested that carbon tariffs may be unable to decrease GHG emissions within global supply chains if the carbon tariff policies are inconsistent in the upstream and downstream countries within the value chain.

In BD-REGU, the stakeholders assumed European policies to aim at more market-based solutions instead of direct incentives. Direct production subsidies have been considered less favourable than, e.g., temporary investment incentives by Finnish wood industry experts based on the risk of market distortion [20]. A particular market distortion could take place if only secondary-wood-flow-based production was subsidized or if production based on virgin wood resources was penalized, for example, with higher taxation. In such a scenario, the main products of primary industries, such as sawnwood products, could increase their production costs in comparison to byproduct processing and utilization in manufacturing. Such a distortion should be accepted only up to the correction of related externalities. For example, subsidies for secondary wood flow production may be needed to incentivize technological changes and their positive spillovers. However, restrictions on resource uses, production volumes, and consumption indicate that the economic system will be more regulated in BD-REGU than in other scenarios. In CONNECT, for example, free trade was assumed to be promoted to prevent conflicts between countries, and the market guidance was based on incentives on, e.g., smart buildings and green and blue constructed environments. Additionally, the decrease in consumption was promoted through taxation, where the producer pays for excess production, and the consumer pays for the external impacts of over-consumption. In practice, it might not be possible to monitor the consumption of an individual. Instead, perhaps, a global income-based progressive taxation system might take place, as recommended in the study of Grigoryev et al. (2020) [36], to mitigate emissions more efficiently in the countries where rapidly increasing household incomes lead to higher carbon footprints. However, this recommended approach by Grigoryev et al. (2020) [36] was aimed at developing countries since their relative household income increase is relatively fast compared to, e.g., European countries.

The political efforts in CONNECT also pointed toward reducing material consumption and extending the lifetime of products, for example, in the construction sector. Additionally, CONNECT called for a complete landfilling ban. Currently, construction and maintenance cause the highest GHG emissions among societal needs globally due to especially needs in developing countries [3]. Thus, investing in prolonged lifetimes and green infrastructure may be an even more effective approach to decrease emissions, but only if the 'know-how' is also upscaled outside Europe.

Policy measures should be aligned to ensure that they do not counteract each other since this could cause significant damage to the economy. In all the scenarios, the priorities seemed consistent since, for example, consumption reductions and natural resource utilization restrictions were driven at the same time by the circular economy. Additionally, the scenarios implied more versatile raw material options to reduce dependency on fossil fuels and reduce GHG emissions without relying on a single raw material or technology. It has already been recognized that the strategies to keep climate change below a 1.5 °C increase require a wide set of policy measures. Jewell and Cherp (2020) [37] stated that these measures could be divided into two main groups: in the first group, actions are practices that already exist and are generally economically feasible, including, e.g., changes in industrial processes, low-carbon urban solutions, carbon pricing, forestry, and land-use. The second group contains carbon-capture technologies and other solutions that are still under development and currently lack evidence of widespread economic feasibility. Since demand-reduction actions and advanced negative-emission technologies should be driven at the same time, it is criticized that it may not be politically feasible worldwide [37]. Reflecting on this, these scenarios might be overly optimistic regarding political actions and their economic feasibility.

4.3. Implications on Finnish Forests and Forest Owners

Biodiversity enhancement through public subsidies in BD-REGU could offer more versatile forest-utilization possibilities for forest owners, especially if nature-based tourism brought financial profits at the same time. On the other hand, if sufficient subsidies are not provided for forest-harvesting companies and land owners, strict legislation can lead to income losses [38]. Mönkkönen et al. (2009) [39] found that voluntary forest conservation implemented through sufficient cost efficiency and properly set site selection criteria can efficiently improve biodiversity in southern Finnish forests. However, it is also fair to assume that biodiversity-based directives affect the structure of Finnish forests as well as forest-management methods throughout the country. For example, more uneven-aged forest stands, retention forestry, and continuous-cover forestry implementation could go mainstream since these methods are argued to offer more biodiversity benefits compared to traditional even-aged forests or clear-cutting methods [40,41]. In even-aged forests, the decrease in energy wood use could affect the management of young forests, making the management less profitable. Thus, an uneven-aged forest-management style could seem preferable for forest owners when it is applicable.

The multifunctionality of forests could also offer non-material income for forest owners in Finland. In CONNECT, virtual tourism in connection with Finnish nature tourism was assumed to grow its market share, which also could help to drive biodiversity restoration and enhancement by improving people's attitudes toward conservation efforts [42]. Increased nature tourism and real-time virtual forest tourism could also encourage forest owners to consider biodiversity more if it would increase the tourism value. The popularity of green areas would also show in the urban areas in CONNECT because of the requirement to have a certain percentile green/blue infra of the urban area. This could also increase the utilization of wood-based materials in construction, along with introducing more urban forests.

4.4. Conflicts and Synergies between Scenario Pathways and Illustrations

The stakeholders assumed harvest levels to increase around 8–43% in each scenario, which seems contradicting considering strict natural-resource-utilization policies. The harvest level in 2019 was 73 million cubic metres in Finland [23], meaning the harvest level would be around 104 million cubic metres, which is close to the total growth of Finnish forests to date. To justify this assumption, the stakeholders stated that a drastic increase could be possible if intensive forest management boosting the growth of forest was introduced. They also assumed that increased CO_2 concentration in the atmosphere would increase the growth of forests further, e.g., nitrogen fertilization and the utilization of clone trees may increase the net growth, depending on the forest type [43–45], and improved wood mobilization actions may also help to increase biomass availability for the forest industries [46]. However, as the impacts depend on the forest type, a 43% increment in net growth seems unreachable. Previous studies, e.g., Heinonen et al. (2018) [47], have also shown that it is possible to keep the annual harvest target of 80 Mt under IPCC mild and moderate climate-change scenarios while maintaining the current annual growth level, which is still much less than assumed by the stakeholders in this study. In addition, Heinonen et al. (2018) [47] showed in the same simulation study that the harvest target could not be reached in the severe climate change scenario. Compared to this, CIRCULAR, with the increase of 8%, seems to be the most realistic. However, the stakeholders did not consider a situation where the harvest levels would decrease or the productivity of forests would decline due to, e.g., forest fires or increased pathogen attacks. This is a possible outcome, and it should be included in further scenario analysis.

In the product portfolio visualization of BD-REGU (Figure 3), the sawnwood products and chemical and dissolving pulp were assumed to comprise the highest percentage (22%), supporting the assumption that wood-based construction and hygiene products are accepted as carbon-neutral solutions. Previous research has, however, revealed that high market acceptance and demand for wood-based construction might not be enough, and revision of the building codes [48] as well as more efficient policy measures are required [49,50]. In BD-REGU, the high share of chemical and dissolving pulp may also be related to the textile industry, and dissolving pulp can be used as a raw material for textile production, replacing water-use-intensive cotton, for example. In the European policies, it was stated that restrictions for biofuel utilization could be introduced. Considering this, the share of liquid biofuels (13%) seems high in the portfolio. Advanced biofuels, on the other hand, may be an exception because the sawmilling and pulp sectors generate a lot of side streams, and biofuel plant integration may be the most practical approach to increase resource efficiency [51].

In CIRCULAR, chemical and dissolving pulp was the biggest single intermediate product group in terms of share in the product portfolio (23%), followed by mechanical and half-chemical pulp production (14%) (Figure 4). The numerical demonstration is in line with global and European policy paths encouraging new bio-based technologies because chemical pulp offers a wide range of end-uses in neighbouring industries (such as textile, composite, and medical). Considering that fossil fuel utilization has already decreased radically by 2040 in this scenario, the demand for these bio-based material solutions could be high, especially as the consumption was assumed to still follow an increasing trend globally. At the same time, traditional sawnwood-based products had a relatively low share in the product portfolio (11%), but it may not mean a general decrease in long-lifetime products because the panels, CLT, and composites and hybrids had an 11% share in the product portfolio. Thus, long-lifetime products would still cover 33% altogether in the product portfolio, which is 8% higher than the present. Sawnwood products and panels cover around 25% of the total product portfolio to date, whereas composites and hybrids still have too small of production volumes to show up in the total shares [52].

In CONNECT, the requirement of 'green infrastructures' could mean utilizing more sawnwood, panel/CLT, and wood-based composite/hybrid products, which explains their high share in the product portfolio (39%). These industries also produce a variety of high-quality byproducts, such as sawdust, wood chips, and bark, which can be used to develop new products such as biochemicals, biofuels, and more wood-based composites. CONNECT assumed strong growth for renewable-based material businesses and energy generation. However, the share of wood-based heat and power production in the product portfolio was only 5%.

4.5. Methodology Recommendations

Although qualitative scenario pathways can be compared against each other, it is not reasonable to compare scenarios' numerical illustrations against each other since the illustrations are based on individuals' perceptions of production volumes, and each stakeholder has only visualized their own group scenario. Individual's perception of 'a lot' and 'very little' is subjective to personal experiences and cannot be considered as conclusive [14]. Therefore, energy shares in the product portfolio seem inconsistent. For example, in BD-REGU, the stakeholders assumed restrictions for wood-based biofuels, yet the energy share in the product portfolio was higher than in CIRCULAR, with more allowing politics for wood-based energy. More comparable results could have been attained if each stakeholder gave their visualization for every scenario, not only the one that was formed by their group. However, this would have required an in-depth understanding of the other scenarios, which expands the required focus time and could have negatively affected the participation. An alternative solution could be to select a new stakeholder panel, which would afterwards review and visualize the scenarios. In expert- panel-based studies, it is possible to use a separate expert panel in different study phases [53]. Another option would be to set a new objective expert panel evaluating the scenarios, giving their own visualization, and comparing the first- and second-round visualizations. This kind of study setting has been used in, e.g., the medical field study of Roposch et al. (2014) [54].

In their feedback, some of the stakeholders stated that in the illustration task, it was challenging to allocate the shares for different intermediate product groups, as there were many of them. Some stakeholders also stated that it would have been useful to see the current harvest level and product portfolio. However, we decided not to provide that information since it could have hindered future-oriented thinking and lead to psychological restrictions on perceptions of what is possible. However, the illustration task could be made easier by providing a virtual calculation sheet for product share allocation.

5. Conclusions

This study utilized a participatory approach to exploratively create scenarios for the Finnish forest sector development in 2040 that also take a broader perspective on global circumstances creating the frames for international markets and policies. Scarcity of food and water due to climate change, as well as over-consumption, social crises, and the threat of conflicts, were considered likely by the stakeholders and thus recurring themes in all scenarios. Some of these dark future visions are already present; this only highlights the importance of future studies aiming to seek solutions to prevent these negative pathways. In this scenario study, the consequential policy priorities globally and legislation and regulation at the European level accelerated the shift from a fossil-fuel-based economy to a non-fossil-fuel-based economy, simultaneously with demand-restriction policies, to minimize negative impacts. Very similar implications were presented in the study of Bengston et al. (2020) [55], which explored the consequences of abrupt climate change.

The stakeholders considered that the international policies invented in the scenarios would imply, after all, positive renewal for the Finnish wood-based product portfolios and major leaps in clean energy technology development and adoption. However, under the scenario policies, the carbon footprints of value chains were considered more important than, e.g., material. Thus, it is not self-evident all wood-based production would be considered sustainable under these scenarios. For example, in the 'BD-REGU' scenario, only wood-based hygiene products and construction materials were considered 'acceptable by the public and policies'. In general, it was considered likely that high-added-value products such as modern wood-based construction, composites, textiles, polymers, and chemicals would increase their market share while wood utilization for energy would radically decrease due to new technologies. Finnish outlook reports have assumed that forest biomass use in energy generation can be increased together with carbon-capture and bioenergy utilization (BECCS) technologies in low-carbon scenarios [27,56]. Based on the results of our study, relying too much on wood energy in renewable energy strategies can expose a political risk if shifts in political attitudes toward wood-based energy take place. The shifts in opinions at the EU level can already be seen [54]. Nevertheless, businesses should be prepared to reinvent their business models to decrease virgin wood utilization and instead focus on side streams and waste wood.

Looking forward, the three scenarios of this study described very different pathways in which the role of society, institutions, and businesses has been shown to be driving forces of different magnitudes of success. Further research inspired by our study could explore the general question of 'what and who drives (successful and sustainable) innovation?' In particular, this could explore the role and effectiveness of regulatory vs. voluntary frameworks on one side (institutions as drivers of change), social innovation and lifestyle philosophy (society as drivers of change), and sustainable business models on the other (society and business as drivers of change). The different futures our planet is potentially heading toward strongly depend on what we humans do with the time, minds, and resources given to us.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14169999/s1, Material S1: Workshop; Figure S1: Ketso sheet and leaves; Table S1: Invented global main trends extracted into a table; Table S2: Invented European -level policies extracted into a table; Table S3: Invented European R&D funding priorities extracted into a table; Table S4: Invented results of the question "What kind of actors benefit of the scenario circumstances in Finland?" extracted into a table; Table S5: Invented results of the question "Who will not benefit/suffers from the scenario circumstances?" extracted into a table; Table S6: Individual scenario illustrations (product portfolio and harvest level).

Author Contributions: Conceptualization: J.K. and V.W.; methodology planning, J.K. and V.W.; methodology implementation, J.K., V.W., P.L. and M.K.; analysis, J.K. and V.W.; writing—original draft preparation, J.K. and J.L.; writing—review and editing, J.K., V.W., M.K., P.L., J.L., T.O. and D.T. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the research project 'Structural changes in the Finnish wood-based sector, and market and employment impacts accordingly in 2040' (22EN033KE), funded by the Metsämiesten Säätiö Foundation.

Data Availability Statement: All data supporting reported results can be found within this article and Supplementary Material.

Acknowledgments: The authors would like to thank all the participants of the workshop and Minna Korhonen for the editorial help.

Conflicts of Interest: The authors declare no conflict of interest.

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