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Frontiers of the forest-based bioeconomy – a European Delphi study

Abstract

The European forest-based sector is undergoing major changes, while, at the same time, the role of a forest-based bioeconomy is being politically discussed. The aim of this study is to elicit expert views on critical changes in the sector through an outlook towards 2030 and 2050, as well as to analyse how these views relate to the understanding of bioeconomy. The study employs a three-round Delphi survey with 41 experts representing different sectors and societal perspectives across Europe. Forty statements based on initial explorative interviews were evaluated by the panel in two consecutive rounds of web-based questionnaires. Results reveal the highest consensus among panellists relates to the diversification of the forest industries and the dependence of the sector on climate and energy policies. The greatest dispersion of expert opinions was found to relate to the possible discontinuation of bioenergy market growth, the possible segregation of forest management, change in forest ownership structure, and the shortage of biomass supply in the long–run. Additionally, the concept of bioeconomy was regarded by the majority as a vision for the future, rather than a depiction of real changes. Notably, major change regarding the significance of the sector, and specifically a transition towards a well-developed forest based bioeconomy, was not expected towards 2030 without significant change in the policy framework.

Keywords: bioeconomy; dissensus-based Delphi; foresight; forest-based sector; trends; uncertainties

1 Introduction

The global population is likely to increase by 2.3 billion people by 2050 (Glenn & Florescu, 2015). At the same time, the global economy and related welfare are expected to increase disproportionately (Kharas, 2017). These massive global changes are bound to impact all economic sectors and aspects of life. The forest-based sector is expected to play a role in addressing the decoupling of societal welfare and the environmental burden, particularly in terms of reducing the dependence on non-renewable materials (Antikainen et al., 2017), as well as reaching other UN Sustainable Development Goals (Hetemäki et al., 2017; EC, 2018).

Aggestam & Wolfslehner (2018) call for assessing the impacts of changes in the operating environment across sectors and addressing the wide range of demands being placed on forest resources. Indeed, the European forest-based sector has been facing major changes in recent decades, driven, in particular, by digitalisation, changing global competitive advantages and consumption patterns as well as shifting societal perceptions towards forest use and forest ecosystem services. These trends are valid at the global level, but particularly so in Europe (Hetemäki, 2014; Winkel & Sotirov, 2016). For example, the outlook on forest products markets appears outdated, due to structural changes in the demand elasticities of forest products in the 2000s (e.g., Hurmekoski & Hetemäki, 2013; Rougieux & Damette, 2018). For graphic papers, wood pulp and wood fuel, the demand patterns seem completely opposite in the 2000s compared to the 20th century (FAOSTAT, 2016; Jonsson et al., 2017). These changes have been satisfactorily explained and captured only for the graphic papers market (e.g., Johnston, 2016) – printed media is gradually being substituted for electronic media. On the other hand, new products are emerging, such as wood-based textiles, biofuels, packaging products, and engineered wood products which are likely to gain importance in the coming decades (Hurmekoski et al., 2018).

The purpose of foresight is not to forecast the future, but rather "*to discover or invent, examine and evaluate, and propose possible, probable and preferable futures*" (Bell, 2003). Foresight studies focusing on the forest-based sector are generally characterized by quantitative methods, non-participatory approach, and single factor focus (Hoogstra-Klein et al., 2017). The evidence-based methodology provides consistent estimates of the consequences of selected policy choices in an otherwise fixed system (Hurmekoski & Hetemäki, 2013). That is, model-based and evidence-based approaches are most valid for a stable operating environment and predictable changes. In the same token, these approaches face challenges when the converse is true, for example, due to structural changes such as changing product demand patters and new products emerging to markets. Consequently, if the objective is to identify and understand the possible deviations from the prevailing trends and structures, one needs to use also other methods and foresight approaches (Hurmekoski & Hetemäki, 2013; Hetemäki & Hurmekoski, 2016; Schuell & Hoogstra-Klein, 2017). In exploring uncertain futures where business-as-usual is no longer an appropriate expectation, qualitative and participative approaches can prove useful in diversifying the future developments and identifying new possible future pathways (de Bruin et al., 2017).

A number of foresight studies have explored generic future trends and uncertainties that are also relevant for the forest-based sector (e.g., Saritas & Smith, 2011; Saritas & Nugroho, 2012; Kim et al., 2013; Glenn & Florescu, 2015). Furthermore, several studies have discussed the implications of global drivers of change specifically on the future prospects of the forest-based sector (e.g., Lindahl & Westholm, 2010; Jonsson, 2011; Hetemäki, 2014; Nilsson, 2015; Hagemann et al., 2016). Many of these studies have taken a Delphi survey approach (e.g., Pätäri, 2010; Lehtonen & Tykkyläinen, 2014; Näyhä & Pesonen, 2014; Korhonen et al., 2015; Cuhls et al., 2016; Packalen et al., 2016), focusing either on a national perspective or a single market (e.g., bioenergy, pulp and paper industry). However, there are very few studies addressing a European-level perspective (Mantau et al., 2010; Pätäri et al., 2016; Toppinen et al., 2017), and even fewer with an extensive scope across the sector (Hetemäki 2014).

The present study contributes to the understanding of the future directions of the European forest-based sector using a Delphi survey, involving a heterogeneous set of expert stakeholders. The objective of this study is, firstly, to explore a wide range of expected changes in the European forest-based sector through expert views and to determine the level of consensus among the survey participants on the issues raised. Secondly, the study aims to identify the primary way(s) of understanding the concept of bioeconomy and to contrast it with the expected outlook for the sector.

The study adopts two distinct time horizons: 2030 and 2050. The year 2030 has been the time horizon for several previous forest sector outlook studies (e.g., Mantau et al., 2010; UNECE & FAO, 2011). By 2030, some new products and climate and energy policies can be expected, yet no large structural transformations (Hetemäki, 2014; Hurmekoski et al., 2018), whereas by 2050, also major changes are possible. While 2050 may be too far away for market assessments in the private sector, a longer time horizon is necessary for covering, for example, forest ecosystems and forest management perspectives (UNECE & FAO, 2018). Importantly, the years 2030 and 2050 represent established benchmarks for EU climate and energy policy (e.g., EC, 2014; EC, 2018). The explicit assessment of alternative timescales in a foresight study is supported by, e.g., Westholm et al. (2015), who regard it as key to understanding complex developments. The extension of time horizon may also influence the uniformity of the experts' views on the future.

2 The forest-based bioeconomy

The paper does not use the concepts "forest-based sector" and "forest-based bioeconomy" interchangeably. Forest sector refers to the established economic sector comprising forestry (class A2 in the NACE classification of economic activities) and the forest-based industries (NACE C16 & C17), and in certain contexts also to further forest-related ecosystem services.

In contrast, the bioeconomy is presented in this context as a political concept (Winkel, 2017). Essentially, the concept of bioeconomy depicts a greater reliance of an economy on biomass instead of non-renewable materials (Ollikainen, 2014). However, various understandings of the concept co-exist (Kleinschmit et al., 2014). For example, Bugge et al. (2016) distinguish three indistinct types of visions: a biotechnology vision, a bio-resource vision, and a bio-ecology vision, corresponding to the vision documents of OECD, European Commission, and European Technology Platform, respectively. Winkel et al. (2017) adds the concept of a "biosociety" to this, involving societal participation, awareness and sustainable consumption. So far, one of the most encompassing definitions of the bioeconomy has been used by Hetemäki et al. (2017). They outline a circular bioeconomy and define it to include natural capital, all ecosystem services and related management, and the circular economy concept.

The varying scopes and connotations make designing policies to support a growing bioeconomy challenging (Purkus et al., 2017). Moreover, the perceptions of the bioeconomy appear to be progressing in time. As noted by Pfau et al. (2014), referring to 'sustainable bioeconomy' leaves it unclear whether there may also be an unsustainable bioeconomy—whether it is seen a goal, or if it is self-evidently sustainable. The earlier bioeconomy concepts and strategies (EC, 2012) tended to emphasise economic aspects over environmental sustainability issues (Ollikainen, 2014; Ramcilovic-Suominen & Pülzl, 2016). Improved environmental sustainability was perceived as an inherent feature of the forest-based bioeconomy rather than something to be pursued or guaranteed (Staffas et al., 2013). However, Hetemäki et al. (2017) and the updated EU Bioeconomy strategy (EC, 2018) explicitly acknowledge the necessity not to take sustainability as given, but rather design strategies and polices that also aim to advance environmental sustainability.

Although a growing number of studies on the bioeconomy and its forest-based specification are being published, the bioeconomy remains a multifaceted concept, both in breadth (sectors represented) and in depth (rationales, visions, values, direction, and drivers) (Bugge et al., 2016). Exploring these dimensions is an integral part of this study, along with juxtaposing these views to expected futures.

3 Data and methods

3.1 Data collection and analysis

This study follows a Delphi survey approach. The Delphi method is generally accepted as a method for examining complex, uncertain, and difficult-to-quantify topics (Hetemäki et al., 2016), as it combines elements from evidence, creativity, expertise and interaction under a single framework (Popper, 2008). Delphi surveys are based on conventional survey techniques, yet with a number of defining characteristics, including expertise, anonymity, iteration and controlled feedback (Woudenberg, 1991). In essence, Delphi surveys use an iterative process

of involving and confronting expert judgements (Linstone and Turoff, 2002). A Delphi survey consists of a minimum of two rounds, with an idea to iterate the survey towards the most relevant avenues, as well as to capture the potential impacts on expert opinions when confronting arguments of fellow experts and the distributions of numeric ratings of previous rounds (Linstone and Turoff, 2002).

Due to the lack of a universal standard and a certain amount of 'greyness' of the technique (Hasson & Keeney, 2011), there are inherent limitations and weaknesses related to, for example, the selection of panellists, the formulation of statements, or the method of data analysis (Pätäri et al. 2016). Key strategies for reducing biases in our approach were to use both qualitative and quantitative measurements (Hasson & Keeney 2011), to emphasise supporting and opposing arguments (Winkler & Moser, 2016), and to target a highly heterogeneous panel (ibid.). The heterogeneity may, on the other hand, be also seen as a limitation, as it may limit the depth of inquiry as several issues are beyond the competency of individual panellists. Addressing more detailed questions may also require applying complementary research approaches (Hasson & Keeney, 2011), or more targeted Delphi studies (e.g., Toppinen et al., 2017).

There are alternative Delphi techniques (Rowe & Wright, 2011), with two major variations: i) Consensus Delphi, seeking a shared understanding among the experts, and ii) Policy Delphi seeking to persuade experts to express all possible options for the support or rejection of evidence (Turoff, 1970). Following the trend in the emphases of forest sector related Delphi studies (e.g., Pätäri, 2010), this study takes the latter perspective to explore the range of future options rather than seeking to generate decisions. Specifically, we follow the 'Argument Delphi' variation (Kuusi, 1999), whose primary aim is to develop relevant arguments and expose underlying reasons for different opinions on a specific issue (Hasson & Keeney, 2011).

In this study, a three-stage data gathering process was applied, consisting of one round of semi-structured telephone interviews followed by two rounds of web-based questionnaires (Fig. 1). The survey period extended from June 2016 to February 2017. The main rationale of the first round was to explore a wide range of factors relating to the research questions (cf. Panwar & Hansen, 2009). The purpose of the second round was to initially determine the level of agreement for a number of key statements based on the interviews. The third round gave the opportunity for the panellists to reflect on the opinions of others by reiterating their views by providing (counter) arguments or changing their opinion to those statements with no consensus based on the second round results.

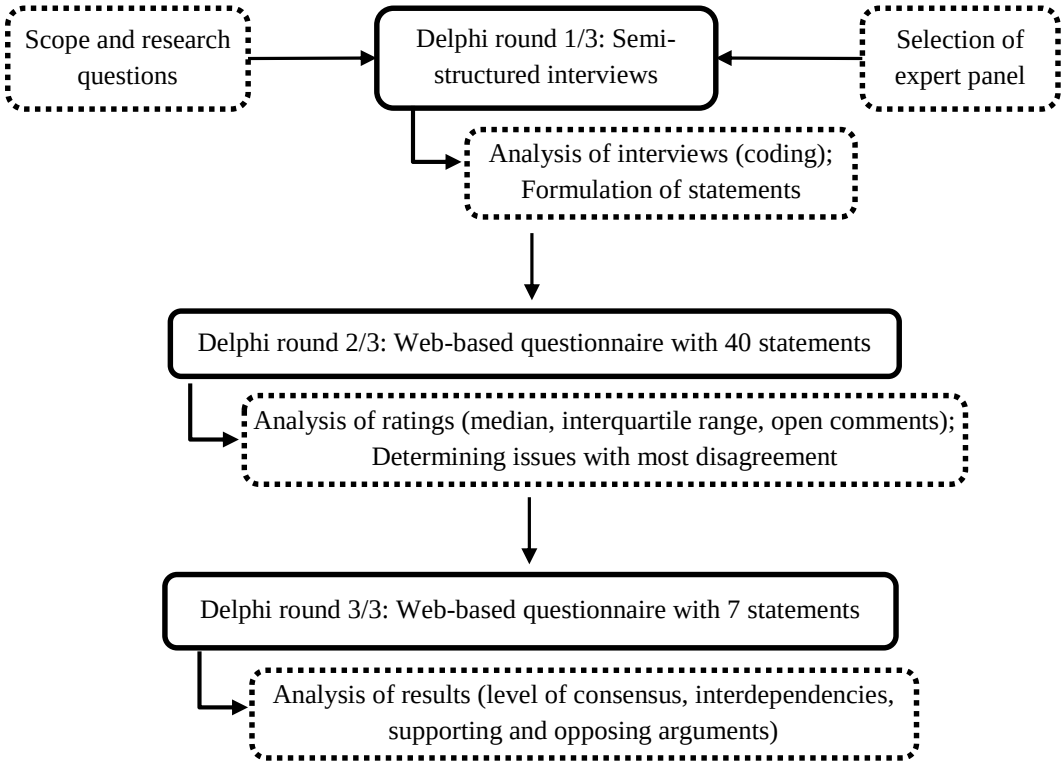

Figure 1. Delphi process applied in this study.

The first round took an explorative approach with 41 interviews. Three test interviews were carried out prior to contacting the panel, with only minor modifications to the interview frame (see Appendix 1) The interview recordings were fully transcribed and subsequently coded using MAXQDA. The coding was conducted in two rounds and followed inductively the thematic content of the text, aiming to identify key statements of the interviewees and order them in a thematic context (see Saldaña, 2012). In the first coding round, the data were condensed into shorter and more manageable units to facilitate a categorization of identified factors (initial coding), with the aim of facilitating the analysis of a large amount of text. In the second coding round, the initial codes, i.e., the shortened text fragments, were categorized into emerging thematic categories by grouping the initial codes into as homogeneous groups as possible. The coding was performed by two different researchers for each section with constant comparison of their respective coding findings to achieve intercoder reliability. During the coding process, particularly typical and interesting in vivo quotations were extracted.

Overall, the interviews resulted in a reasonable rate of data saturation, meaning that uncovering new statements based on further interviews would have been unlikely. However, the rate and extent of saturation varied from one question to another. Particularly for the question on expected changes in the forest-based sector, there were themes that were not brought forward by more than one or two panellists in the end, due to the non-restrictive way of posing the question and possibly due to the high variance in the backgrounds of the panellists. This said, the 41 interviews were clearly sufficient in formulating an understanding on the most common expectations, as these topics began to be repeated well before reaching the final interviews.

Saturation was also reached for the question on the bioeconomy concept, as markedly different responses were no longer formulated in later interviews.

The second stage took the shape of a web-based questionnaire, the design of which was based entirely on the findings from the interviews. The interview coding document was used to formulate five distinctive viewpoints on understanding the forest-based bioeconomy and to gather forty statements on issues that gained most (positive or negative) attention among the panelists so as to convey the main findings of the interviews (cf. Toppinen et al. 2017). Due to the vast amount of data gathered in the first round, many issues were excluded from further analysis. That is, the forty statements do not portray the full picture, but only capture the most common or the most surprising issues.

The main rationale of the second round was to distinguish issues that portray a high level of consensus from issues that arouse controversy (cf. Näyhä & Pesonen 2014). This provided a means for testing the plausibility and consistency of the first round results through the quantification of information (Van Notten et al., 2003). The respondents were asked to rate the statements on a seven-point Likert scale (from 'completely disagree', through 'neither agree nor disagree', to 'completely agree'), including a short introductory text and an option for commenting each section. Seven-point Likert scale was selected as it has superior reliability, validity and discriminating power in comparison to simpler scales (Preston and Colman, 2000). The statements were grouped under six general categories based on the interview coding document.

The degree of consensus on the statements was evaluated by median and interquartile range (IQR). Median represents a 'typical' rating by pinpointing the middle value. In contrast, IQR is a measure for the dispersion of the ratings (e.g., Jiang et al., 2017), effectively calculating the range between third and first quartile, or the middle fifty percent of data. While the IQR indicates the distribution of opinions, the median gives additional information whether the consensus was connected to a more indifferent evaluation (i.e. neither agree or disagree) or was indicating a strong support or opposition towards a statement.

The third Delphi round was a direct follow-up for the second round. The seven most contested statements were selected and presented back to the respondents. Contestation of statements was thereby evaluated through the lowest degree of consensus, that is, the seven selected statements described issues with most disagreement among the panellists ($IQR \geq 3$). Statements that were considered too general (addressed more in depth in other statements) or too specific (requiring too much substance expertise given the high heterogeneity of the panel) were excluded from the selection. Hence, the third round put particular emphasis on the contradictions and disagreement arising from the data in order to find out if experts would change their statements when confronted with divergent opinions. Thus, the dispersion of ratings and key qualitative supporting and opposing arguments from the previous rounds were made available for the participants, providing them the opportunity to learn from the arguments of others and to either confirm or change their views accordingly (cf. Lehtonen & Tykkyläinen, 2014). After collecting all data in that third round, a commonly used threshold ($IQR \leq 2$) was adopted to

signify apparent consensus (e.g., Jiang et al., 2017), with all other statements remaining contested.

As a rule, the responses were treated uniformly, irrespective of the panellists' backgrounds. However, a Kruskal–Wallis test, a non-parametric equivalent of a one-way analysis of variance, was used to test if significant differences exist with respect to respondents' sectoral affiliation and substance expertise. A Mann Whitney U test was used as a post-hoc to the Kruskal–Wallis test to determine which categories of sectoral affiliation and substance expertise influenced the content of statements and their evaluation by experts, i.e. where significant differences were found in accordance to such categories. These tests have been performed on all issues listed in the second round questionnaire. Responses to issues listed in the third round questionnaire were compared to the same responses from the second round questionnaire through a Wilcoxon Matched Pairs Signed-Rank test. This non-parametric test was used to assess whether the medians of two samples differ, i.e., if there are differences between groups in the strength of average opinions. This procedure is an alternative to more widely used Student's t-test, with the advantage that the samples need not to be normally distributed. The results of all statistical tests are presented in Appendix II (Tables A1-A3), and referred to where statistically significant differences were found.

Finally, the extracted expert quotations from all three rounds were grouped with respect to four key categories (market, technology, policy/governance, environment) and assigned a number (e.g., "M3" for market expert #3). However, some arguments had to be treated as anonymous, since not all respondents identified themselves in the two online questionnaires.

3.2 Selection of panellists

In a Delphi study, the group of respondents consists of a purposive sample of experts, referred to as a Delphi panel (Tapio et al., 2011). Since the characteristics of the panel influence the outcomes of the survey, the selection process requires a careful and systematic approach. In this study, an expertise matrix was developed to create a diverse and complementary panel of experts (e.g., Varho & Tapio, 2013). The selection aimed at an even distribution between four different categories of expert background: i) forest products markets, ii) technology development, iii) policy and society, and iv) environmental issues. Moreover, for the market and technology categories, an even distribution along the forest-based industry value chain was targeted, including the following sub-categories: forestry, bioenergy, pulp & paper, biochemicals and fibres, primary wood products, secondary wood products, and other (outside the forest-based sector). In addition to these two primary criteria for the selection matrix, a sufficient coverage of different regions and sectors was considered important. The final panel was settled when each cell of the selection matrix was populated with at least one high-ranking expert who had consented to participate the survey (Table 1). The panelists were identified primarily by direct and indirect personal contacts and by screening relevant institutions.

Few of the initial contacts were unable or unwilling to join the panel. In these occasions, replacements with a similar profile were identified and contacted. The first round included a total of 41 experts that participated the interviews. The response rates for the follow-up web-based questionnaires, as compared to the first round, were 88% (n = 36) in the second round, and 46% (n = 19) in the third round. The panel constellation remained unchanged for the three stages.

Table 1. Expert background (self-evaluated in the first web-based questionnaire).

		Number of respondents	**Share of all respondents**
Sector	Science/research	15	42 %
	Public authority or public policy maker	5	14 %
	Industry	4	11 %
	NGO	2	6 %
	Consultancy/single expert	2	6 %
	Other	2	6 %
	No answer	6	17 %
Predominant substance expertise	Policy/governance	8	22 %
	Environment	6	17 %
	Markets	6	17 %
	Technology	5	14 %
	Other (mainly forest management)	5	14 %
	No answer	6	17 %
Predominant regional focus	Entire Europe or EU	12	33 %
	International	7	19 %
	Spain	3	8 %
	Finland	2	6 %
	Germany	2	6 %
	France	1	3 %
	Portugal	1	3 %
	Sweden	1	3 %
	No answer	7	19 %

4 RESULTS

4.1 Understanding the concept of a forest-based bioeconomy

During the interviews, a majority of respondents regarded the concept of forest-based bioeconomy as something new and different compared to the existing forest-based sector. The main arguments supporting the novelty of the concept related to the need for substituting fossil fuels at least partly based on new technologies or products, to the diminishing boundaries between sectors and industries (particularly the chemical sector), as well as to more general sustainability aspects**,** such as cascading and energy and material efficiency. In the initial interview round, however, there were also respondents who considered the concept of a forest-

based bioeconomy as irrelevant or nothing new. The variance of answers in this regard was remarkable, as shown in the following quotes:

"*Bioeconomy is a real alternative to the dangers and to the limitations of the carbon economy … and also can provide a new opportunity for innovation and for creating jobs and growth*" (T5, first round)

"*Bioeconomy is [seen as] sort of the golden way forward that is going to answer all our questions, which I find very difficult to see*" (P13, first round)

"*This word forest-based bioeconomy is just a pretentious way of saying forest-based economy*" (P9, first round)

While some interviewees limit the concept only to forest biomass production and related products, a slight majority of interviewees showed a broader understanding of the boundaries, and included services, or broader ecosystem services in addition to biomass, in the definition.

Eventually, five distinct ways of understanding the concept could be identified from the interview (first Delphi round) responses. The individual answers within the first round often included elements from more than one identified category, with the main ambiguity being whether bioeconomy stands for real expected changes occurring in the existing forest-based sector or a far-away vision that expands the concept beyond the present-day forest-based sector. Thus, in the subsequent questionnaire (second Delphi round), experts were asked to choose which of the five ways they related to the most. Three quarters of the panellists ended up choosing the option 'vision for the future', coupled with the expectation of a necessary or desirable paradigm shift (Table 2). While this doesn't remove the various nuances around the concept of forest-based bioeconomy, the result strongly supports a transformative function for the concept.

Table 2. Understanding the concept of a forest-based bioeconomy.

Understanding of the concept[1]	**Key rationales and drivers**[1]	**Share of experts**	
		First round[2]	Second round
1. A vision for the future: A necessary or desirable paradigm shift – an economy that is essentially built on the innovative use of sustainably sourced regenerative natural resources, as opposed to an economy based mostly on fossil resources.	• A sustainable society using renewable resources such as forests • A new economic system, free of fossil resources	51%	75%
2. A concept to analyze and describe real changes: The concept refers to observable current and expected future changes in the forest sector, such as the diversification of the end uses of wood, diminishing industry boundaries, or the commercialization of forest ecosystem services.	• More favourable conditions for the forest-based sector – new emerging markets • Merging of forest-based bioeconomy into a wider bioeconomy context • Growing importance of overall low carbon economy • Diversification of economy	12%	11%

3. A synonym for the forest sector: The term does not mean something essentially new – it can be used interchangeably with the concept of forest-based sector.	• The forest-based sector has always been a bioeconomy • It is an economic sector, based on sustainable forest management	27%	11%
4. A useful lobbying concept that, for instance, gives a new identity and critical mass for the bio-based sectors.	• The sector needs to be renamed periodically to follow the spirit of time • The term unites the land use sectors to make them more powerful together, and to balance them against the importance of other sectors that have it much easier to be supported	5%	3%
5. A problematic lobbying concept that, for instance, narrows down the perspective on forests to biomass and industrial uses.	• The increasing political prominence of forest industry may diminish the prominence of other functions of the forest than raw material supply • The concept alone will not be viable unless it is embedded in other trending concepts (such as circular economy)	5%	0%

[1] Formulated utilizing the results from the first round

[2] Approximated from interviews – The first round responses may contain elements from more than one category.

4.2 Expected changes in the European forest-based sector

Interviewees described a large variety of expected changes in the first round of the Delphi. This broad range of topics was captured in forty statements that were evaluated by the panel in the second round in a subsequent online questionnaire. Seven statements showing most disagreement were revisited in a third round follow-up questionnaire. Tables 3 and 4 show the final ratings for the forty statements for the 2030 and 2050 time frames, respectively. Applying a conventional threshold (IQR $\leq$ 2), consensus was reached in 75% (30 out of 40) of the statements after three rounds, while ten statements (#1–#10) remained contested.

Based on responses from the second-round questionnaire, there were no crucial differences in the opinions of experts with respect to their sectoral affiliation (research, industry, etc.) or substance expertise (technology, policy, etc.). With regard to the sectoral affiliation of the experts, significant differences (at 0.05 level) in opinions were identified for only three out of forty statements (#10, #19, #28). The comparison of answers between the third round and the second round shows significant differences in responses (at 0.05 significance) for all statements. It can be argued that more important than the test of differences in the central tendency (median) is the change in IQR – it has decreased in all cases but one (#1).

Two different time frames (2030 and 2050) were used to explore the future drivers for the forest-based sector. Perhaps unsurprisingly, the panel opinions were more dispersed at the 2050 timescale compared to 2030 timescale, as indicated by the interquartile ranges (Tables 3 and 4). The results further suggest that two contradicting overall lines of argumentation can be identified from the data: i) relatively minor changes can be expected by 2030, yet nothing

remains stable by 2050, or ii) the same trends identified for 2030 will continue towards 2050 more or less intensively.

4.2.1 Expected changes towards 2030

Towards 2030, a prominent finding was that changes in the operating environment will have decisive influence on the future outlook of the sector, as opposed to changes originating within the sector itself. Notably, the future development of the forest-based sector was seen as being critically dependent on policies (#36). Of those policies having an impact on the development of the European forest-based sector, climate and energy policies were clearly seen to be the most decisive (#38). In this context, a few interviewees pointed out that policy cannot create demand for forest products, unless meeting strict sustainability requirements:

"*It is all subject to policy. If you leave it to the market, the business-as-usual scenario would be assumed without a policy intervention. Then there would clearly be a decline in forest products in Europe*" (E2, first round).

Despite these prerequisites, the forest industries were expected to keep growing towards 2030 (#12). Consequently, also the demand for wood was expected to continue significantly increasing (#35), leading to increasing prices and imports (#22). This growth was mostly attributable to emerging new uses of wood, particularly in construction (#32). In this regard, the expert panel clearly expected an increase in business complexity, i.e., new value chains, partnerships, alliances, customers, etc., generally referred to as 'diversification' (#37). With new markets in wood construction, textiles, and substitutes for petrochemicals, the boundaries between the existing industries were expected to diminish (#27). While forest industries are targeting new markets, other industries (e.g. the chemical industry) may increasingly utilize wood-based feedstocks:

"*The industry will not grow until 2030 with existing products only*" (M7, interview)

"*Petrochemical companies have all the infrastructure … Why would it make sense that the forest industry goes and builds its own? … conversion of existing refining petrochemical centres into suitable for biomass refining is already a clear trend happening"* (T8, first round).

The broad spectrum of ecosystem services was noted to be a part of the diversification of the forest-based sector towards 2030, particularly in Central Europe (#26). While the services sector was expected to increase, it was not necessarily expected to translate to a major economic contribution for the sector. The orientation on ecosystem services seems to be strongly linked to differences in regional interests, so that such transition is not necessarily to be expected in the Northern countries (#6). Although not explicitly brought forward by the panellists, a shift towards other ecosystem services could also increase trade-offs with biomass production, thus possibly resulting in conflicts:

"*More demand for timber products, more demand for bioenergy, but also more demand for biodiversity conservation, for carbon storage, … human wellbeing in terms of recreation, spiritual values and more demand for water and soil protection"* (P11, first round)

"*The carbon service of wood retained in the forest … won't be compensated until at least 2030 … any real or virtual benefits are likely to be absorbed at the national level, rather than accruing to economic operators*" (anonymous, third round)

Regional differences across Europe were almost unanimously expected to remain or even intensify (#29, #39). On one hand, interviewees saw distinct physical conditions as a decisive factor, which could even accelerate due to climate change having a particularly negative impact in Southern Europe. On the other hand, distinct cultural and societal views that are generally seen as being more favourable for wood production in Northern Europe were expected to continue. While a growing relative importance of Eastern Europe on account of a larger untapped resource base was brought up by a few interviewees (#29), the majority saw the Northern and Central European forest sector strengthening their leading position in the bioeconomy development (#25, #39), and Southern Europe focusing on ecosystem services (#19). Regarding the latter statement (#19), business and consultant experts disagreed, while public authorities and scientists agreed. Central Europe was expected to strengthen its lead in the European bioeconomy (#25), yet also to shift from biomass to other ecosystem services (#26). This can be interpreted in two ways: Either the forest-based bioeconomy in that region will have a broader focus creating value from different forest ecosystem services, or it indicates challenges for biomass supply in that region due to conflicting societal demands in the future.

The societal perceptions towards forestry covered various standpoints. The perceptions of the general public towards the forest-based sector were considered as negative, with not much change expected towards 2030 (#11). The extractive uses of forests were thought to be perceived differently than that of alternative resources, in that intensive forestry is more visible for the public at a large scale compared to, for example, oil drilling. However, as noted in the third round, it could also become easier in time for the forest sector to receive a societal license to operate, due to the society being increasingly preoccupied with other than environmental problems, such as social disintegration and insecurity, or deterioration of public services. Moreover, one respondent pointed out that the extractive use of forests faces resistance only if it does not visibly benefit the public, making it a matter of inclusion. Some experts underlined that the sector itself needs to be committed to adjusting to changing societal demands (#14). Reversely, the perceptions of the larger public could be affected by communication and awareness raising activities, e.g. in creating more support for the use of wood:

"There is no wood culture throughout most of Europe … there's very little sympathy with the whole idea of exploiting forests commercially" (M9, first round)

"*For policy makers and the normal citizens it seems that we are going to cut all the trees to make everything out of trees instead of using fossil fuels … sounds pretty terrifying*" (M7, first round)

The most uncertain development in the 2030 timeframe, as well as for the entire study, was the outlook for bioenergy market (#1). The possible discontinuation of bioenergy market growth was mostly attributed to the policy dependency (#21) and the possible impact of alternative renewable energy technologies (#34) (Fig. 2). The majority of respondents bringing up bioenergy during the interviews had a sceptical view, stating that the demand for wood-based bioenergy will level off, although possibly only after 2030. Several interviewees had strong normative views on this issue, arguing for a policy change to decrease forest bioenergy use, as it may crowd out other uses of wood biomass:

"*The wood flowing into the whole energy sector prevents us from doing, not even developing, from even thinking of doing more … innovative things"* (P6, first round).

"*There will be strong pressures to 'keep growing', but the spectacular (and often counterproductive) increases of 'the past decade' will be difficult to replicate"* (anonymous, third round).

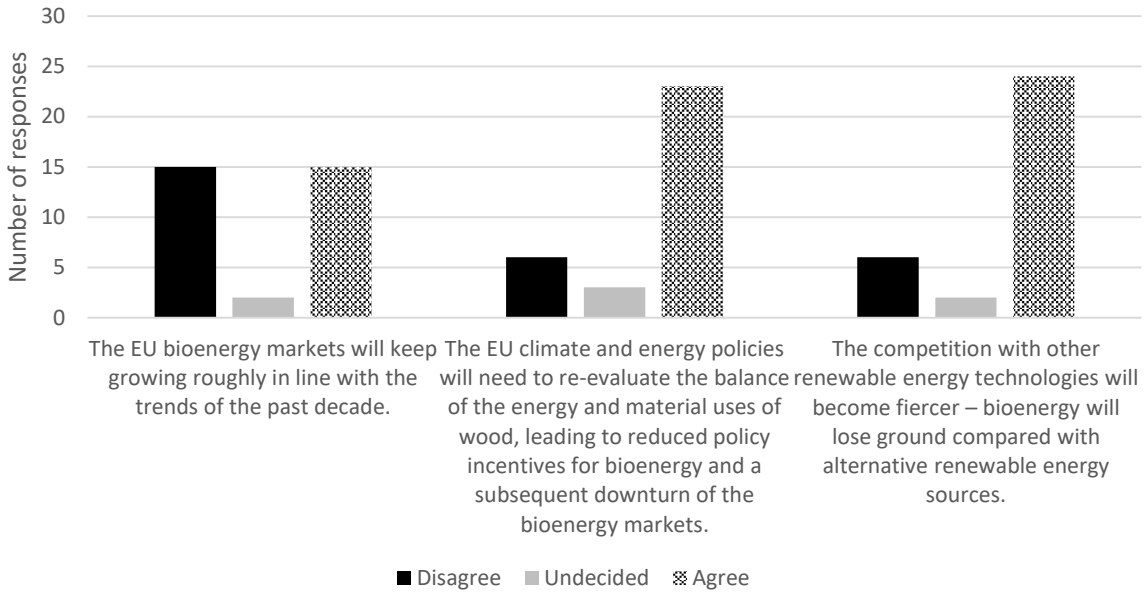

Figure 2. Rating for the bioenergy-related statements (for 2030) on the second round.

Table 3. Statements for 2030, sorted by the final IQR (interquartile range) score (the higher the IQR, the greater the disagreement between experts) and showing the median evaluation (based on the evaluation of the statements with a 7-point Likert scale with 1 = fully disagree, …, 4 = neither agree, nor disagree, …, 7 = fully agree)

ID	Theme	Statement	Median	IQR
#1	Bioenergy markets	The EU bioenergy markets will keep growing roughly in line with the trends of the past decade.	5	3.5
#6	Regional aspects	The focus of the Northern European forest sector will significantly shift from forest biomass towards a broad spectrum of ecosystem services.	3	3
#11	Societal issues	The societal perception on the intensive material use of Europe's forests will not change much in favour of the forest biomass harvest.	4	2
#12	Industry development	The forest industry turnover in Europe will stagnate or decline, due to the stagnating economy and unfavourable demographic conditions (low population growth, urbanization, ageing).	3	2
#14	Societal issues	The European forest sector will not be able to adjust to societal demands.	3	2
#15	Societal issues	High rates of unemployment and immigration will provide a cheap workforce that will make the European forest-based sector more competitive in the future.	3	2
#17	Industry development	The competitiveness of the European forest industries will deteriorate relative to Asia and the Americas.	4	2
#19	Regional aspects	The Southern European forest sector will focus on ecosystem services instead of forest industries.	4	2
#20	Regional aspects	Russia's forest sector will develop significantly and have major implications for the European forest products markets.	4	2
#21	Bioenergy markets	The EU climate and energy policies will need to re-evaluate the balance of the energy and material uses of wood, leading to reduced policy incentives for bioenergy and a subsequent downturn of the bioenergy markets.	5	2
#22	Balance of wood supply and demand	There will be a shortage of wood biomass in Europe towards 2030 as demand cannot be fully covered by supply, leading to a price hike and increased imports.	5	2
#24	Societal issues	Employment will shift towards a smaller number but higher qualified jobs in the forest sector, driven by digitalization, automation and robotics, and the continued concentration of firms.	5	2
#25	Regional aspects	The Central European forest sector will strengthen its position and leadership in the European forest-based bioeconomy development, due to good resource availability and innovation.	5	2
#26	Regional aspects	The focus of the Central European forest sector will significantly shift from forest biomass towards the broader spectrum of forest ecosystem services.	5	2
#27	Industry development	The industry boundaries will become less clear, as the forest industries are moving increasingly to – or being taken up by – e.g., textile, biochemical, pharmaceutical or construction industries.	6	2
#29	Regional aspects	The relative importance of the Northern and Central European forest sector will decline, due to more rapid development in Eastern Europe, which has a greater potential to tap into currently less used natural resources.	3	1
#30	Industry development	Globalization will positively affect the European forest industry.	4	1

#32	Industry development	Wood construction will substantially increase in Europe.	5	1
#34	Bioenergy markets	The competition with other renewable energy technologies will become fiercer – bioenergy will lose ground compared with alternative renewable energy sources.	5	1
#35	Balance of wood supply and demand	The demand for wood biomass in Europe will increase significantly by 2030.	5	1
#36	Societal issues	The future development of the forest-based bioeconomy will critically depend on policies – markets alone will not trigger the necessary investments and innovations.	5	1
#37	Industry development	The forest-based industry value chains and business models will become more diverse.	6	1
#38	Societal issues	Of those policies having impact on the development of the European forest-based bioeconomy, climate and energy policies will be the most decisive.	6	1
#39	Regional aspects	Northern Europe will lead bioeconomy.	6	1
#40	Regional aspects	Europe will lead the global forest-based bioeconomy development.	5	0

4.2.2 Expected changes towards 2050

It was commonly accepted that there is significant inertia in industry transitions, for example, due to long investment cycles. It is therefore only towards 2050 that the core businesses of the forest-based industries were expected to gradually move away from the traditional sawnwood and paper value chains (#13). Two long-term orientations for the forest-based industries were identified in this regard: i) large-scale substitution of fossil and other non-renewable resources such as textiles and chemicals (#28), and ii) high added-value innovations for niche markets such as pharmaceuticals (#33). If seen as complimentary orientations, this could mean pursuing new markets, while at the same time assuming new roles more downstream in the respective value chains. Regarding large-scale substitution (#28), there was a difference in opinion between industry experts who agreed on it, and NGO experts who disagreed. The statement caused disagreement also in regard to substance expertise, in that environment and market experts did not have an opinion, while technology experts agreed with it.

Resulting from the growing global economy and the need to substitute large amounts of fossil and other non-renewable materials, the demand for wood biomass was expected to continue increasing towards 2050 (#23). However, unlike for 2030, it remained contested whether this results in a shortage of wood biomass (#3), for example, due to a shift towards more circular economy. Drivers for reducing the demand for wood resources were also identified, such as decreasing population in Europe, the uptake of alternative renewable energy technologies, and the focus of the industries on higher value and smaller volume products. Overall, the expectations remained somewhat contradictory. Referring to a ‘shortage’ was also noted to be misleading, in that in a market economy, prices balance supply and demand: A growing demand for—or a reduced supply of—biomass eventually leads to increased prices and imports

that clear the theoretical gap. As noted on the third round, finding wood at an affordable price may already pose restrictions for many.

According to the interviewees, contributing to climate change mitigation will require both increasing the forest carbon sink by increasing forest area and halting deforestation and using wood-based products to substitute more carbon intensive products. The increasing pressure on forest resources elicited widely dispersed opinions related to integrated versus segregated forest management (#8, #9). Some experts argued that, on a landscape level, it may be possible to have both an increase in segregation and also an increase in integrated approaches. Further identified pressures for change in forest management related to increased conservation of forests (#16), climate change adaptation, and opportunities created by new technology grouped under the concept of 'industry 4.0' (#18). Although not agreed upon by the panel, long-term technological advances could lead to reduced relevance of the quality of biomass compared the sheer quantity (#5). It could also radically increase the amount and reduce the cost of available information, which could lead to the opposite direction.

In reference to the interview question regarding the aspects that will change the least towards 2030, the most often mentioned aspects related to forest ownership, along with forest management. In strong contrast, in the longer timeframe, some respondents explicitly argued that there are accumulating pressures for a tenure reform, as well as significant changes in forest management (#2). One important aspect was that industries need to have a better control of raw material supply in the future, as the demand for wood material was expected to keep growing. Yet judging on the average ratings, forest ownership was not necessarily expected to change away from private owners (#10), nor from the forest industry to other industries (#7). Moreover, others argued that as the strategic value of land increases through an increasing scarcity, or as the significance of the bio-based sector rebounds and private forest owners become more reliant on the income from forests again, private owners could be less likely to sell. The change in forest ownership (#10) was agreed upon by public authority and industry expert groups, whereas scientists and NGOs disagreed.

Towards 2050, bioenergy was expected to continue to play a crucial yet relatively minor role, as a buffer product for the shortages in for example wind and solar energy. That is, biomass was seen to play a role as a bridging technology, whose availability can be regulated more easily compared to wind or solar power. However, several respondents referred to the possibility of technological breakthroughs also in energy storage, which would challenge the role of biomass as the only consistent source of renewable energy, i.e., not only for peak loads. The importance of circular processes was also emphasised, i.e., to use the waste from other processes as energy. As noted during the second round, growth in wood construction would result in increased availability of side streams for bioenergy. It can be concluded that the use of biomass for energy was not expected to disappear, but the nature and scale of the bioenergy markets might face significant changes already by 2030, and more notably after that:

"*Solar energy capturing and storage systems … will lead to a strong decrease in demand for renewable energy produced from biomass. Actually the current period is only an intermediate phase until then*" (M10, first round).

Table 4. Statements for 2050, sorted by the final IQR (interquartile range) score (the higher the IQR, the greater the disagreement between experts) and showing the median evaluation (based on the evaluation of the statements with a 7-point Likert scale with 1 = fully disagree, …, 4 = neither agree, nor disagree, …, 7 = fully agree)

ID	Theme	Statement	Median	IQR
#2	Forest management and ownership	Forest management and forest ownership will not change significantly.	3	3.5
#3	Balance of wood supply and demand	There will be no shortage on wood biomass in Europe by 2050.	5	3
#4	Industry development	The focus of the European forest sector will shift towards services and non-material products, particularly from forest biomass related value creation to ones based on non-material ecosystem services (e.g., recreation, nature-based tourism).	4	3
#5	Forest management and ownership	The quality aspects and species composition will have reduced significance, due to technological change (from fibre scale industry to molecular scale).	3	3
#7	Forest management and ownership	Other industries – such as the petrochemical industry – will extend their feedstock supply & increase the ownership of forests.	4	3
#8	Forest management and ownership	Integrative land uses (e.g., agroforestry) will become more common in Europe, driven by increased pressure on land use (e.g., competition with food production).	5	3
#9	Forest management and ownership	There will be a stronger segregation into forest biomass production oriented (rural) areas and ecosystem services oriented (urban) forest areas, while multifunctional/integrated approaches will largely diminish.	5	2.5
#10	Forest management and ownership	Forest ownership will significantly change away from small-scale private forest owners.	2.5	2.5
#13	Industry development	The current paper and sawnwood value chains will remain the core businesses of the European forest industries.	3	2
#16	Forest management and ownership	The area of strictly conserved forests will strongly increase.	4	2
#18	Industry development	The forest industries will be able to capitalize on the emerging disruptive technologies or "industry 4.0" (e.g., automation, industrial internet, 3D-printing) more than the competing European industries.	4	2
#23	Balance of wood supply and demand	The demand for wood biomass in Europe will increase significantly by 2050.	5	2
#28	Industry development	The focus of the European forest industries will be on large-scale substitution of fossil and other non-renewable materials in applications such as textiles, plastics, construction materials, or biofuels.	6	2
#31	Industry development	The chemical forest industries (pulp, paper, biochemicals, biofuels, etc.) will be economically more important than the wood product industries	4	1

		(sawnwood, engineered wood products, composites, etc.).		
#33	Industry development	The focus of the European forest industries will be on high added-value innovations for niche markets, such as biochemicals, pharmaceuticals, cosmetics, or food additives.	5	1

5 DISCUSSION AND CONCLUSIONS

This study explores major trends and uncertainties that may impact the European forest-based sector towards 2030 and 2050 and contrasts them with the understanding of the forest-based bioeconomy concept, through eliciting and contrasting the views of leading European forest-based sector experts.

The results suggest that the future of the forest-based sector depends crucially on the developments in the operating environment, specifically in the climate and energy policy framework. One of the most prominent trends towards 2030 was an increase in business diversity, while the most prominent uncertainty towards 2030 was the discontinuation of bioenergy market growth, due to an expected phase-out of policy support and the increasing competition through advancing alternative renewable energy technologies. The expected diversification of the forest-based sector relates to currently emerging and new products, and a subsequently continued increase of biomass demand until 2030. However, it is only towards 2050 that a large-scale substitution of non-renewable materials for wood could take place. The gradual change in the key factors for a forest based bioeconomy reflects the unavoidable path dependencies of some of these factors (e.g., forest ownership or management), or only gradually increasing impacts of some long-term trends (e.g., climate change). It may, however, also point at a general tendency of experts to postpone more difficult to imagine changes in the longer time perspective.

Contrasting the results on the expected changes in the European forest sector to the themes that typically feature prominently in long-term forest sector outlook studies reveals several similarities, albeit the expert teams conducting these studies were hardly overlapping with our Delphi panel. Typical themes in previous outlook studies include climate change mitigation and adaptation, forest products markets and the sufficiency of wood resources, renewable energy, protecting and enhancing biodiversity, and political and institutional frameworks (Mantau et al., 2010; UNECE & FAO, 2011; Hetemäki, 2014). Hetemäki (2014) and UNECE (2018) show a broader range of topics, including those brought forward in our study, such as discontinued growth for bioenergy, the diversification of forest products markets, the role of services, and changing societal perceptions. Such results may facilitate acknowledging trends and drivers, such as changing societal values, which remain difficult to capture with quantitative modelling approaches.

The results point to five possible ways of understanding the concept of forest-based bioeconomy: (i) A vision for the future, (ii) a concept to analyze and describe real changes, (iii) a synonym for the forest-based sector, (iv) a useful lobbying concept, and (v) a problematic lobbying concept. Literature provides direct support for at least three of the five categories, notably *a vision* (Goven & Pavone 2015, Bugge et al. 2016, Hodge et al. 2017), a *useful lobbying concept* (Hilgartner 2007, Pülzl et al. 2014, Ollikainen 2014, Goven & Pavone 2015), and a *problematic lobbying* or *greenwashing concept* of the extractive industries (Staffas et al. 2013, Pfau et al. 2014, Ollikainen 2014, Goven & Pavone 2015).

The five different perspectives of the forest-based bioeconomy can be grouped into two 'competing' conceptualizations. The 'real changes', 'useful' and 'problematic lobby concept' perspectives all put emphasis on the industrial, new and added-value uses of forest biomass, and diminishing of borders with the chemical and biotechnology industries. This is in line with the first EU bioeconomy strategy and framing of sustainability problems though the narrative of technological advances backing economic interests (O'Mahony and van Ark, 2003; van Ark, 2006; Overbeek et al, 2016). In this context, the focus is on biotechnology and its innovative potential, and not so much on the sectors that manage natural resources – forestry, agriculture and fisheries (Schmid et al., 2012). In this way the solutions to "*... sustainability challenges are often orientated towards the partisan agendas of dominant stakeholders and myopic technological fixes, while marginalizing other civil society actors and critical insights from social sciences*" (Diedrich et al., 2011, p. 935). Following this line of thought, the forest-based bioeconomy is 'useful' from the perspective of the industry actors, and 'problematic' for the traditional forestry actors. Also, the inclusion of ecosystem services in forest-based bioeconomy can be seen as the realization of the life as surplus concept (Cooper, 2008), by which the neoliberalized political economy, i.e. where 'free market' paradigm is expanded to 'nature', which is thus commodified.

The implicit argument that other 'forms' of sustainability will arise in the wake of economic sustainability as set in the first EU bioeconomy strategy mirrors the now surpassed 'wake theory' (Glück, 1982) of forestry, by which all non-timber products and services of the forests are delivered "*... in the wake of regular forestry for timber production*" (Glück, 1997). Such framing of sustainability has also now been surpassed by the second EU bioeconomy strategy (Hetemäki et al., 2017), by which 'overall sustainability' is not implicitly acknowledged to trail the economic development of bioeconomy, but rather that different design strategies and polices are needed to advance also environmental and social aspects of sustainability. In this context, the supply-oriented sectors of the bioeconomy such as forestry are equally important as industries. The importance of forestry in the forest-based bioeconomy is evident in the 'vision for the future' and the 'forest-sector synonym' perspectives, even though they have clearly opposite standpoints on how the bioeconomy differs from the status quo. Such 'balanced' framing of bioeconomy has long been advocated for (e.g. Vanloqueren and Baret, 2009, Birch et al, 2010, Norton, 2016). Unlike the former perspective that favors classical top-down 'knowledge transfer' in the context of knowledge-creation, it favors 'knowledge

exchange', i.e., more participatory approach which recognizes different kinds of knowledge (including local knowledge; Cooper et al., 2009).

It is understandable that our expert panel has focused on the importance of forest and forestry for the European bioeconomy. This is a perspective that can be contested, as the dominant framing of European bioeconomy focuses on biotechnology and cascading use biological resources (EC, 2011; Schmid et al, 2012), so that forests may at best be seen as a resource-base or at least be marginalized (Pülzl et al, 2014; Giurca, 2018). Instead, Hetemäki et al. (2017), Winkel (2017) and the new EU bioeconomy strategy (EC 2018) provide already a wider view of the European bioeconomy by considering also the environmental sustainability explicitly, as well as the services related to forests. Aside emphasizing the importance of forestry, the panelists' understanding of a forest-based bioeconomy mirrors the prevailing understanding of European bioeconomy, which is characterized by a diversification of the sector and a diminishing of boundaries between economic sectors, and large-scale substitution and technological innovation (Staffas et al, 2013; Richardson, 2012, Hetemäki et al., 2017). In this light, the inclusion of other ecosystem services than biomass provision within the forest-based bioeconomy is in line with the depiction of the bioeconomy concept in natural capital studies and the more recent bioeconomy reports (Costanza et al., 1997; Helm, 2015; Hetemäki at el., 2017; EC, 2018). At the same time, the inclusion of the broad spectrum of forest ecosystem services in the bioeconomy concept by many experts is a remarkable departure from the traditionally biomass centered bioeconomy concept in many earlier studies and policy documents (see also Winkel, 2017).

The strong support for the "visionary" understanding of the concept as a necessary and desirable economic paradigm shift indicates a performative character of the concept for the European forest-based sector. If this performative or visionary function of the bioeconomy concept is central, the forest-based bioeconomy needs to relate to visions of a broader sustainability transition. This may be achieved through connecting the concept to green economy (D'Amato et al., 2017), natural capital and circular economy (Hetemäki et al., 2017), or a "biosociety" (Winkel, 2017). Based on this study, the forest sector would benefit from being seen as part of a major sustainability pathway that responds to the diversity of societal demands towards forests. Such a vision could guarantee a societal license to operate and merit political support and visibility, which many of the consulted experts consider to be crucial for the future of the forest-based sector.

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Appendix I

Interview questions

1) The "transition towards a bioeconomy" is an increasingly debated topic in Europe. How would you define a *forest based bioeconomy* in 1-2 sentences?
2) What will be in your view the up to 3 most significant changes in the European forest-based sector and why?
    a. until 2030?
    b. until 2050?
3) Reversely: What will change the least in the sector towards 2030 and why?
4) Regional differences in Europe: How does the outlook for the sector differ between regions towards 2030 (compared to current situation)?
5) Sustainability is regarded as an important aspect of the bioeconomy.
    a. How would you define sustainability in the context of a European forest based bioeconomy in 1-2 sentences?
    b. Which 3 key indicators would you use to monitor the sustainability of the European forest based bioeconomy and why?
6) Is there anything else you would like to mention regarding these themes?

APPENDIX II

Results of statistical tests

Table A1. Differences in responses with respect to sectoral affiliation and substance expertise across all statements (Kruskal Wallis Test)

ID	Statement	Sectoral affiliation (df=5)		Substance expertise (df=4)	
		Chi-Square	Asymp. Sig.	Chi-Square	Asymp. Sig.
#1	The EU bioenergy markets will keep growing roughly in line with the trends of the past decade.	1.426	0.921	0.671	0.955
#2	Forest management and forest ownership will not change significantly.	2.19	0.822	7.262	0.123
#3	There will be no shortage on wood biomass in Europe by 2050.	8.834	0.116	2.381	0.666
#4	The focus of the European forest sector will shift towards services and non-material products, particularly from forest biomass related value creation to ones based on non-material ecosystem services (e.g., recreation, nature-based tourism).	2.278	0.809	2.236	0.692
#5	The quality aspects and species composition will have reduced significance, due to technological change (from fibre scale industry to molecular scale).	6.59	0.253	6.831	0.145
#6	The focus of the Northern European forest sector will significantly shift from forest biomass towards a broad spectrum of ecosystem services.	2.462	0.782	1.29	0.863
#7	Other industries – such as the petrochemical industry – will extend their feedstock supply & increase the ownership of forests.	6.468	0.263	4.425	0.352
#8	Integrative land uses (e.g., agroforestry) will become more common in Europe, driven by increased pressure on land use (e.g., competition with food production).	3.011	0.698	4.935	0.294
#9	There will be a stronger segregation into forest biomass production oriented (rural) areas and ecosystem services oriented (urban) forest areas, while multifunctional/integrated approaches will largely diminish.	6.627	0.25	3.169	0.53
#10	Forest ownership will significantly change away from small-scale private forest owners.	11.113	0.049	0.959	0.916
#11	The societal perception on the intensive material use of Europe's forests will not change much in favour of the forest biomass harvest.	0.214	0.999	2.274	0.686
#12	The forest industry turnover in Europe will stagnate or decline, due to the stagnating economy and unfavourable demographic conditions (low population growth, urbanization, ageing).	2.857	0.722	10.618	0.031
#13	The current paper and sawnwood value chains will remain the core businesses of the European forest industries.	3.859	0.57	1.893	0.755
#14	The European forest sector will not be able to adjust to societal demands.	3.268	0.659	1.229	0.873
#15	High rates of unemployment and immigration will provide a cheap workforce that will make the European forest-based sector more competitive in the future.	2.714	0.744	4.952	0.292
#16	The area of strictly conserved forests will strongly increase.	3.738	0.588	4.297	0.367
#17	The competitiveness of the European forest industries will deteriorate relative to Asia and the Americas.	7.142	0.21	2.292	0.682
#18	The forest industries will be able to capitalize on the emerging disruptive technologies or "industry 4.0" (e.g., automation, industrial internet, 3D-printing) more than the competing European industries.	3.513	0.621	3.145	0.534
#19	The Southern European forest sector will focus on ecosystem services instead of forest industries.	5.542	0.353	0.777	0.941

#20	Russia's forest sector will develop significantly and have major implications for the European forest products markets.	13.029	0.023	6.489	0.165
#21	The EU climate and energy policies will need to re-evaluate the balance of the energy and material uses of wood, leading to reduced policy incentives for bioenergy and a subsequent downturn of the bioenergy markets.	2.214	0.819	0.845	0.932
#22	There will be a shortage of wood biomass in Europe towards 2030 as demand cannot be fully covered by supply, leading to a price hike and increased imports.	10.766	0.056	5.083	0.279
#23	The demand for wood biomass in Europe will increase significantly by 2050.	4.247	0.514	1.496	0.827
#24	Employment will shift towards a smaller number but higher qualified jobs in the forest sector, driven by digitalization, automation and robotics, and the continued concentration of firms.	4.001	0.549	9.309	0.054
#25	The Central European forest sector will strengthen its position and leadership in the European forest-based bioeconomy development, due to good resource availability and innovation.	2.479	0.78	1.129	0.89
#26	The focus of the Central European forest sector will significantly shift from forest biomass towards the broader spectrum of forest ecosystem services.	3.81	0.577	1.601	0.809
#27	The industry boundaries will become less clear, as the forest industries are moving increasingly to – or being taken up by – e.g., textile, biochemical, pharmaceutical or construction industries.	1.729	0.885	3.171	0.53
#28	The focus of the European forest industries will be on large-scale substitution of fossil and other non-renewable materials in applications such as textiles, plastics, construction materials, or biofuels	1.045	0.959	1.557	0.816
#29	The relative importance of the Northern and Central European forest sector will decline, due to more rapid development in Eastern Europe, which has a greater potential to tap into currently less used natural resources.	10.539	0.041	9.675	0.046
#30	Globalization will positively affect the European forest industry.	4.455	0.486	5.192	0.268
#31	The chemical forest industries (pulp, paper, biochemicals, biofuels, etc.) will be economically more important than the wood product industries (sawnwood, engineered wood products, composites, etc.).	1.606	0.9	3.362	0.499
#32	Wood construction will substantially increase in Europe.	0.463	0.993	5.027	0.285
#33	The focus of the European forest industries will be on high added-value innovations for niche markets, such as biochemicals, pharmaceuticals, cosmetics, or food additives	3.063	0.69	1.656	0.799
#34	The competition with other renewable energy technologies will become fiercer – bioenergy will lose ground compared with alternative renewable energy sources.	3.303	0.653	3.285	0.511
#35	The demand for wood biomass in Europe will increase significantly by 2030.	1.617	0.899	1.046	0.903
#36	The future development of the forest-based bioeconomy will critically depend on policies – markets alone will not trigger the necessary investments and innovations.	6.993	0.221	3.707	0.447
#37	The forest-based industry value chains and business models will become more diverse.	2.452	0.784	5.892	0.207
#38	Of those policies having impact on the development of the European forest-based bioeconomy, climate and energy policies will be the most decisive.	0.663	0.985	6.228	0.183
#39	Northern Europe will lead bioeconomy	7.751	0.17	3.031	0.553
#40	Europe will lead the global forest-based bioeconomy development.	6.922	0.227	6.803	0.147

Table A2. Differences in responses with respect to individual categories of sectoral affiliation and substance expertise for individual statements in which significant differences in responses have been noted for these two grouping variables (Mann-Whitney test)

Differences with respect to sectoral affiliation

2. Forest ownership will significantly change away from small-scale private forest owners.									Median opinion by group
Asymtotic significance									
		0	1	2	3	4	5		
Other	0		1	0.7841	0.102	0.8230	0.1045		4.5
Consultancy/single expert	1			1	0.3173	1	0.5361		4
Industry	2				0.0455	0.8836	0.0409		5
NGO	3					0.0404	0.3469		2
Public authority or public policy maker	4						0.0132		5
Science/research	5								3

19. The Southern European forest sector will focus on ecosystem services instead of forest industries.									Median opinion by group
Asymtotic significance									
		0	1	2	3	4	5		
Other	0		0.6830	0.1400	0.2206	0.0444	0.0519		2.5
Consultancy/single expert	1			0.4745	0.6830	0.0678	0.1025		3
Industry	2				0.8025	0.0326	0.1571		3.5
NGO	3					0.0678	0.1611		3.5
Public authority or public policy maker	4						0.0461		6
Science/research	5								5

28. The focus of the European forest industries will be on large-scale substitution of fossil and other non-renewable materials in applications such as textiles, plastics, construction materials, or biofuels									Median opinion by group
Asymtotic significance									
		0	1	2	3	4	5		
Other	0		0.1024	0.4795	0.0832	1	0.2783		4
Consultancy/single expert	1			0.0491	0.3173	0.1554	0.2180		4
Industry	2				0.0455	0.5581	0.0773		6
NGO	3					0.0942	0.0324		3
Public authority or public policy maker	4						0.3669		6
Science/research	5								5

Differences with respect to substance expertise

12. The forest industry turnover in Europe will stagnate or decline, due to the stagnating economy and unfavourable demographic conditions (low population growth, urbanization, ageing).								Median opinion by group
Asymtotic significance								
		0	1	2	3	4		
Other	0		0.1121	0.6379	0.7041	0.0434		4
Environment	1			0.2086	0.0365	0.5459		2.5
Markets	2				0.3671	0.0391		3
Policy/governance	3					0.0058		3.5
Technology	4							2

28. The focus of the European forest industries will be on large-scale substitution of fossil and other non-renewable materials in applications such as textiles, plastics, construction materials, or biofuels								Median opinion by group
Asymtotic significance								
		0	1	2	3	4		
Other	0		0.2759	0.6819	0.0633	0.0112		5
Environment	1			0.5581	0.1985	0.0199		4.5
Markets	2				0.1196	0.0209		4.5
Policy/governance	3					0.3316		6
Technology	4							6

Table A3. Differences between responses in the second and third round questionnaire (Wilcoxon Matched Pairs Signed-Rank Test)

No.1.	Statement	Second round		Third round		Wilcoxon Matched Pairs Signed-Rank Test	
		Median	IQR	Median	IQR	Z	Asymp. Sig. (2-tailed)
1	The EU bioenergy markets will keep growing roughly in line with the trends of the past decade (by 2030)	4	2	5	3.5	-3.2719	0.0010
2	Forest ownership will significantly change away from small-scale private forest owners (by 2030)	4	3	2.5	2.5	-3.0346	0.0024
3	There will be no shortage on wood biomass in Europe (by 2050)	4	4	5	3	-3.7195	0.0001
4	The focus of the European forest sector will shift towards services and non-material products, particularly from forest biomass related value creation to ones based on non-material ecosystem services (e.g., recreation,	3	3	4	3	-3.3722	0.0007

	nature-based tourism) (by 2050)						
9	There will be a stronger segregation into forest biomass production oriented (rural) areas and ecosystem services oriented (urban) forest areas, while multifunctional/integrated approaches (of forest management) will largely diminish (by 2030)	4	3.5	5	2.5	-3.8864	0.0001
11	The societal perception on the intensive material use of Europe's forests will not change much in favour of the forest biomass harvest (by 2030)	4	3	4	2	-3.0948	0.0019
40	Europe will lead the global forest-based bioeconomy development (by 2030)	5	3	5	0	-3.6109	0.0003