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Employment and Working Conditions in the Bioeconomy in Finland and Germany

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The BMBF junior research group Mentalities in flux (flumen) combines sociological and historical research to explore how people's mentalities change in post-fossil transformations and how this change is reflected in the employment structure of society.

Today, there is broad agreement that fossil fuels, due to their limited availability and damaging effects for the climate, will need to be phased out within the coming decades. One proposed alternative is the idea of a bioeconomy, in which raw materials and energy are gained from renewable sources of plant and animal origin.

But this implies more than just a shift to renewable resources. In fact, the whole way modern economies are organized will have to change: Fossil-fueled economies rely on a constantly accelerating linear throughput of materials, from extraction through production and distribution to consumption and waste disposal. In contrast, bio-based economies draw on materials and energy sources that regenerate cyclically. Their production cannot be increased at will, but is subject to the natural limitations of these circular flows of matter and energy.

The historical emergence of economies based on linear flows of fossil resources radically transformed human work and was closely linked to basic mindsets, attitudes and shared imaginations compatible with the logic of constant growth. These mentalities differ between social groups, and they will undergo far-reaching change once again in the transformation toward bio-based economies. In short, mentalities evolve in parallel with the transformations of societies' material and energetic basis – they are: Mentalities in flux.

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flumen MENTALITÄTEN IM FLUSS

Fritz, Martin

Employment and Working Conditions in the Bioeconomy in Finland and Germany

Abstract

This working paper introduces a method of measuring the bioeconomy for the purpose of assessing the social structure and working conditions of persons working in bioeconomic jobs. Previous measurements only allow aggregate level estimations of financial and economic contributions of the bioeconomy. The job classification suggested here is suitable for analysing individual level survey data. By combing information from the sector of economic activity with data on occupation three types of jobs can be distinguished: jobs in the core bioeconomy, jobs in the wider bioeconomy and jobs that are outside the bioeconomy. The classification is applied to a) an analysis of the social structure and working conditions in the Finnish bioeconomy and b) a study of the composition and changes of employment in the German bioeconomy in comparison to the approach of the 'Pilot Report on Monitoring the German Bioeconomy' (Bringezu, Banse, Ahmann et al. 2020). Results show that in the bioeconomy atypical forms of employment occur more often while overall job numbers are declining.

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Keywords

Bioeconomy; monitoring; measurement; employment; working conditions; jobs; social structure; European Labour Force Survey; Germany; Finland

Contents

1. Introduction

In current debates about creating sustainable and just societies, the bioeconomy is increasingly marshalled as a solution to multiple challenges. Shifting from fossil to renewable resources not only in energy production but also in the use and processing of materials would lower ecological pressures and help mitigate climate change. Moreover, increasing investment in bio-based sectors would stimulate green growth and create jobs – both helpful to counter the expected negative economic consequences of the transition away from fossil fuels-based economies. Additionally, efforts to advance research and development in the fields of life sciences and biotechnology are hoped to lead to innovations that provide new ways of using and processing materials, and inventions that allow for completely new applications.

Previous research on the potential of the bioeconomy to provide these hoped-for solutions has highlighted problems such as increasing land use pressure and conflicts when more bio-based resources are produced (Backhouse, Rodríguez and Tittor 2019, Backhouse and Lehmann 2020) as well as the general biophysical limits of generating biomass (Giampietro 2019). As a consequence, the most unrealistic promises are adjusted and moderated in more recent policy documents (Eversberg and Holz 2020).

There are also concerns about a 'hijacking' of the term bioeconomy. Although fossil fuels are replaced by biomass, the '…dominant design and economic organization that the powerful stakeholders […] are trying to establish will almost certainly mimic those of the petrochemical industry.' (Vivien, Nieddu, Befort et al. 2019, p. 195). Efforts to advance the transition towards a bioeconomy, however, are proceeding constantly: Thereby national pathways vary between a focus on the substitution of fossil fuels with bio-based raw materials, productivity increases in bio-based primary sectors, efficiency increases in biomass utilization as well as value creation and addition through the innovative application of biological principles and processes (Dietz, Börner, Förster et al. 2018). As more and more countries are setting up national and regional bioeconomy strategies and projects, social and political science research develops frameworks for the evaluation of the social, economic and ecological consequences of the bioeconomy. In this context, Egenolf and Bringezu (2019) highlight key objectives within the social dimension of the bioeconomy: work safety, social integration, as well as workers' rights, education and training. Their conceptual approach is underpinned by the empirical results of Zeug, Bezama, Moesenfechtel et al. (2019) who conducted a survey among German stakeholders to find priority issues for monitoring the bioeconomy. Important social objectives that were mentioned by the stakeholders were, for example, food security, sustainable consumption and sustainable infrastructures.

More generally, El-Chichakli, von Braun, Lang et al. (2016) point to the need to finding '…ways to measure the bioeconomy's development and its contributions to

the SDGs.' (p. 223). The bioeconomy is expected to contribute to the achievement of a range of Sustainable Development Goals (SDGs), for example, no. 2 (zero hunger – through the provision of sufficient food), no. 7 (affordable and clean energy – via the production of biofuels and bioenergy) as well as no. 13 (climate action – substitution of fossil resources), no. 14 and no. 15 (life below water and on land – protecting biodiversity). Particularly relevant for this work is the strong link to SDG no.8 (decent work and economic growth), as most bioeconomy strategies include promises of green growth and increasing profits through innovative biotechnologies as well as the hope for a high number of green jobs that are generated during the transition to a bioeconomy.

Many of the studies on the bioeconomy focus on material flows and economic projections as well as political acceptance of different bioeconomy strategies. But there is still a lack of research on sociological questions such as which social groups work in the bioeconomy or what are the working conditions in the bioeconomy. In a systematic literature review Sanz-Hernández, Esteban and Garrido (2019) diagnose a huge lack of empirical social science studies of the bioeconomy. Within the few studies they found, the topics of health, bioenergy, agriculture and food, waste and governance are predominating while the working conditions and the social backgrounds of workers in the bioeconomy are mostly neglected.

However, both issues are important to explore in the context of research on social-ecological transformations, as the different social backgrounds people have and the conditions under which they work have strong influence on their perceptions, attitudes and values (in short: their mentalities (see Eversberg, Fritz, Holz et al. 2021)) as well as their ways of living. If the bioeconomy is to be expanded in post-fossil transformations, according mentalities and practices might become more widespread and shape society more strongly. These could, for example, include an orientation to principles of sufficiency, practices aiming at producing 'Zero Waste' and preferences for renewable energy.

There is, however, no guarantee that existing fossil mentalities automatically change towards more bioeconomic mindsets because people start working in the bioeconomy. In fact, there are several and diverging expert visions as well as societal views of the bioeconomy, including some oriented at sufficiency but also others aimed at capitalist growth (Eversberg and Fritz 2022, Hausknost, Schriefl, Lauk et al. 2017). Thus, fossil mentalities may still prevail also within a bio-based circular economy if other, more deeply engrained, dimensions of the economy remain unchanged: the belief that market forces alone regulate the production and distribution of goods without democratic participation, hierarchical dominance over nature and socially disadvantaged groups, the strive for extracting more and more natural resources to fuel economic growth etc. In order to find the niches where the bioeconomy is associated with changing mindsets and practices as well as to discover the spots where fossil

mentalities persist, it is necessary to study the social conditions and inequalities within this economic sector.

A major obstacle to analysing the social structure and the working conditions in the bioeconomy is the way in which the bioeconomy is operationalized in to-date existing concepts: The size of the bioeconomy in terms of value added and jobs is estimated via the bio-based shares of economic sectors drawing on additional statistical information about the material flows between and within these economic sectors. This approach only allows for a more abstract economic assessment at aggregate levels, but in order to explore social and working conditions it is necessary to focus on actual jobs at the individual level. By combining information about the economic sectors with the occupations persons work in, this paper creates a typology of jobs that can be applied to investigate the bioeconomy in more detail.

The working paper is organized as follows: In the next chapter existing concepts to measure the bioeconomy are introduced and reviewed regarding their potential to measure social structures and working conditions in the bioeconomy. The statistical classification of economic sectors is presented and it is discussed which sectors belong to the bioeconomy. Then a new job typology is created by cross-tabulating economic sectors by occupations. Using European Union Labour Force Survey (EU-LFS) data, the job typology is subsequently applied to two examples: First, the Finnish bioeconomy in the year 2018 is analysed with regard to its social composition and working conditions in more detail. Second, the same is done for the bioeconomy in Germany 2018 and complemented by a comparison to the findings of the German bioeconomy monitoring (Bringezu et al. 2020).

The questions to be explored in these analyses are: How much of the employment in the bioeconomy does occur in the different economic sectors such as agriculture, manufacturing and food and beverages service activities? Who works in the bioeconomy in terms of the distribution of women and men, age, education, etc.? Which occupational and employment forms are typical for jobs in the bioeconomy and finally: Is there a difference between the location and duration of working hours inside and outside the bioeconomy? And: Is there a job growth in the bioeconomy or at least a potential to increase employment numbers in the near future? All these questions will be discussed both at the example of Finland and Germany.

2. Operationalizing and Measuring the Bioeconomy

According to the German Ministry of Education and Research, the bioeconomy comprises all parts of the economy which deal with the production of goods and the provision of services that are based on the utilization of renewable biological resources such as plants, animals or microorganisms (Bundesministerium für Bildung und For-

schung 2020). There are many other varying definitions that reflect the different interests of stakeholders such as scientists, policy makers, organizations or private businesses (Kardung, Cingiz, Costenoble et al. 2021). Bugge, Hansen and Klitkou (2016) identify three overarching themes or visions that appear frequently in bioeconomy approaches: a biotechnology vision, a bio-resource vision and a bio-ecology vision. Common for all concepts of the bioeconomy are notions of technology, sustainability, circularity, resources, energy and a reference to the fact that the bioeconomy should be integrated more and more in all production and services processes of society and in a variety of economic sectors. Typical sectors are, for example, agriculture, forestry, bioenergy, parts of the chemical and pharmaceutical industry, the food industry, industrial biotechnology, paper and textile production as well as environmental protection. A problem for the comparability of the different approaches and a main difference between them is that some concepts include the provision of services related to bio-based resources and others do not.

The definition of the bioeconomy given in the original 2012 bioeconomy strategy of the European Commission, for example, only considers 'agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries'[1] thus leaving out service activities such as trading with biological resources or working in a restaurant. Measurements of the bioeconomy that rely on this definition incorporate all economic activities related to the production and manufacturing of biomass, yet there is a number of 'hybrid sectors' (Ronzon and M'Barek 2018) whose bio-based extent cannot be measured directly. Here '*…experts estimate the proportion of biomass incorporated in each product produced by the hybrid sector; and, at sector level, the proportion of biomass incorporated in all products from this sector makes up the sectoral bio-based share*.' (ibid., p.3).

D'Adamo, Falcone and Morone (2020) build on this work and introduce the 'socio-economic indicator for the bioeconomy': a measure of the socio-economic performance of bioeconomy sectors. Their selection of bioeconomy sectors is the same as those of many others: the primary sector plus manufacturing (where bio-based shares were partly estimated) and bio-electricity. This is despite them basing their work on a definition of the bioeconomy that they relate to the Global Bioeconomy Summit in 2018 which is much more comprehensive and includes, e.g. services with bio-based products: '*The bioeconomy is the production, utilization, and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information, products, processes, and services across all economic sectors aiming toward a sustainable economy*' (cited in ibid., p.3). What do they mean with the socio-economic performance of bioeconomy sectors? As most other bioeconomy monitoring efforts they focus on assessing the number of jobs in the bioeconomy and some economic

1 https://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf, p.3

parameters such as turnover and value added. The quality of those jobs, working conditions and socio-demographic parameters such as age and gender of the persons working in the bioeconomy are not investigated.

These examples show that measurement concepts of the bioeconomy vary with regard to the sectors that are included or excluded. Concepts can be inclusive (considering as much sectors as possible) or exclusive (leaving out certain sectors). In this context, Mittra and Zoukas (2020) point to the problem that measurement and monitoring concepts can be used strategically to '…make claims about current and future value' (p. 16) or to 'artificially inflate the economic contributions of the bioeconomy' (p. 18). Bracco, Calicioglu, Gomez San Juan et al. (2018) investigated different national methods used for the measurement, monitoring, and reporting of bioeconomy contributions to the total economy. They observe that most countries only measure the contribution to gross domestic product, turnover, and employment. Moreover, they identify an imbalance between the aims of monitoring and the measurement methods: ecological and social impacts of the bioeconomy are often discussed, but not actually measured. One of the few exceptions is the study of Mattila, Judl, Macombe et al. (2018) who explored the social impacts of the bioeconomy in the case of the Finnish wood product supply chain. Conducting a social life cycle assessment, they found that the main social issues were health, safety and gender inequality occurring mainly in those parts of the bioeconomic values chains that are actually outside of Finland.

Another exception is demonstrated by Alviar, García-Suaza, Ramírez-Gómez et al. (2021) who measure the size of the bioeconomy via input-output matrices for the case of Colombia: They estimate the bio-based share of all non-primary sector economic activities as equivalent to the proportion of input from the primary sector. This way, their analyses also include services. In terms of value added their results show *'…that the primary sector accounts for 52 percent of the bioeconomy, while the manufacturing sector represents 28 percent and the services sector approximately 20 percent'* (p. 10). In terms of employment, they find that 18 percent of the jobs in Colombia are in the bioeconomy, of those 71 percent are in the primary sector, 11.5 in manufacturing and 17.6 in services. Interestingly, the authors also explored job quality in the bioeconomy by looking at the rate of informality of jobs (employees who have no work contract). They found that informality is higher among bioeconomy employment than in total employment: While the average incidence in Colombia is 50 percent, in the primary sector it is as high as 85 percent, in manufacturing it is below the average with 43 percent and in services again higher with 69 percent.

Jander and Grundmann (2019) suggest to use a quite different and interesting way to monitor the transition to a bioeconomy: resource substitution via the substitution share indicator (SSI). It measures the extent to which fossil resources already have been replaced by bio-based resources. Their analyses show that the transition to a bioeconomy is still in the very early stages. In Germany, for example, the rate of the

bio-based substitution of fossil resources in the transport fuels sectors lies between 3.1 and 3.4 percent.

In summary, most monitoring concepts follow a logic of goods and resources and material flows. While this is appropriate for the scientific and economic assessment of the bioeconomy at an aggregate level, for a social science study of the bioeconomy a different perspective and approach need to be applied: To explore the working conditions and the social structure in and of the bioeconomy, the operationalization of the bioeconomy has to follow the logic of jobs. Individual level data from social surveys can be used to classify jobs into those that belong to the bioeconomy and those that do not. These types of jobs can then be compared in terms of employment and working conditions as well as social characteristics. In order to build such a typology of jobs two factors need to be considered: the *sectors*, and more specifically the economic branches, in which the respondents of the social survey work, and their *occupations* (see Figure 1).

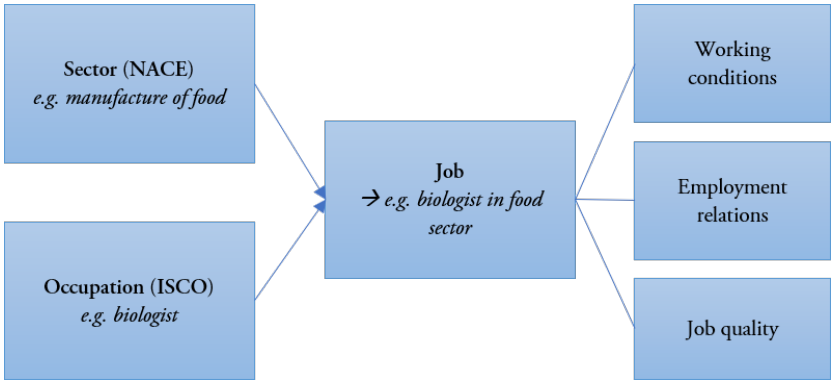

Figure 1: Conceptualizing jobs in the bioeconomy

2.1. The Statistical Classification of Economic Sectors (NACE)

In the European Union the economic sectors and branches are classified in a hierarchical system called '**N**omenclature statistique des **a**ctivités économiques dans la **C**ommunauté **e**uropéenne' (NACE)[2]. At the World level a comparable classification is the United Nations' 'International Standard Industrial Classification of all Economic

2 In English: 'Statistical classification of economic activities in the European Community' EUROSTAT. 2008. *Nace Rev. 2. Statistical Classification of Economic Activities in the European Community*Congress.

Activities' (ISIC) which is derived from NACE but is less detailed (see EUROSTAT 2008, p. 14). The hierarchical structure of NACE consists of four levels: The first level distinguishes 'sections' denominated by the letters from A to U. The code A, for example, indicates economic activities in agriculture, forestry and fishing, and the code C reflects economic activities in the section of manufacturing (see Figure 2). The second level identifies the 'divisions' by a two-digit numerical code, for instance, 01 stands for 'crop and animal production, hunting and related service activities' and is a part of the agriculture section which comprises the divisions 01 – 03 (see Figure 3). The third and fourth level distinguish economic activities further into 'groups' and 'classes' by adding a third and fourth digit to the code. Example: 01.2 within 'crop and animal production' stands for 'growing perennial crops' and within this group 01.26 signifies the class 'growing of oleaginous fruits'. Hence, a person working on an olive farm would get the code 01.26 or simply the code A if for any reason (mostly data privacy) only the one-digit code is available.

Broad Structure of NACE Rev. 2

Section	Title	Divisions
A	Agriculture, forestry and fishing	01 – 03
B	Mining and quarrying	05 – 09
C	Manufacturing	10 – 33
D	Electricity, gas, steam and air conditioning supply	35
E	Water supply; sewerage, waste management and remediation activities	36 – 39
F	Construction	41 – 43
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	45 – 47
H	Transportation and storage	49 – 53
I	Accommodation and food service activities	55 – 56
J	Information and communication	58 – 63
K	Financial and insurance activities	64 – 66
L	Real estate activities	68
M	Professional, scientific and technical activities	69 – 75
N	Administrative and support service activities	77 – 82
O	Public administration and defence; compulsory social security	84
P	Education	85
Q	Human health and social work activities	86 – 88
R	Arts, entertainment and recreation	90 – 93
S	Other service activities	94 – 96
T	Activities of households as employers; u0ndifferentiated goods- and services-producing activities of households for own use	97 – 98
U	Activities of extraterritorial organisations and bodies	99

Figure 2: The broad structure of NACE, source: EUROSTAT (2008, p. 57)

Detailed Structure of NACE Rev. 2

n.e.c. : not elsewhere classified

Division	Group	Class	
			SECTION A — AGRICULTURE, FORESTRYAND FISHING
01			Crop and animal production, hunting and related service activities
	01.1		Growing of non-perennial crops
		01.11	Growing of cereals (except rice), leguminous crops and oil seeds
		01.12	Growing of rice
		01.13	Growing of vegetables and melons, roots and tubers
		01.14	Growing of sugar cane
		01.15	Growing of tobacco
		01.16	Growing of fibre crops
		01.19	Growing of other non-perennial crops
	01.2		Growing of perennial crops
		01.21	Growing of grapes
		01.22	Growing of tropical and subtropical fruits
		01.23	Growing of citrus fruits
		01.24	Growing of pome fruits and stone fruits
		01.25	Growing of other tree and bush fruits and nuts
		01.26	Growing of oleaginous fruits
		01.27	Growing of beverage crops
		01.28	Growing of spices, aromatic, drug and pharmaceutical crops
		01.29	Growing of other perennial crops
	01.3		Plant propagation
		01.30	Plant propagation
	01.4		Animal production
		01.41	Raising of dairycattle
		01.42	Raising of other cattle and buffaloes
		01.43	Raising of horses and other equines
		01.44	Raising of camels and camelids
		01.45	Raising of sheep and goats
		01.46	Raising of swine/pigs
		01.47	Raising of poultry
		01.49	Raising of other animals
	01.5		Mixed farming
		01.50	Mixed farming
	01.6		Support activities to agriculture and post-harvest crop activities
		01.61	Support activities for crop production
		01.62	Support activities for animal production
		01.63	Post-harvest crop activities
		01.64	Seed processing for propagation
	01.7		Hunting, trapping and related service activities
		01.70	Hunting, trapping and related service activities

Figure 3: Some examples in the detailed structure of NACE, source: EUROSTAT (2008, p. 61)

In social surveys, such as the European Social Survey (ESS), the information about respondents' economic activities is often gathered via an open question like the following in the ESS 2018: 'What does/did the firm/organisation you work/worked for mainly make or do?'[3] In the German population census, in which the data for the German part of the European Union Labour Force Survey is gathered, a similar formulation is used and respondents are asked to provide a detailed description of the

3 http://www.europeansocialsurvey.org/docs/round9/fieldwork/source/ESS9_source_questionnaires.pdf, p. 57 [accessed 19.5.2021]

economic branch of the local unit of their company[4]. The answers are later evaluated by data experts and coded into NACE. In case persons are engaged in two or more different economic activities, EUROSTAT (2008) provides guidelines for determining the correct NACE category, usually the economy activity is chosen that makes up the biggest share of the working time of respondents.

Now, which of the sections, divisions, groups and classes within NACE belong to the bioeconomy?

The German pilot report on measuring the bioeconomy (Bringezu et al. 2020) specifies 1) the production of biomass, 2) the bio-based manufacturing of products and 3) bio-based services as elements of the bioeconomy. Thereby 'bio-based' means that products are made completely or partly of renewable resources. In this concept the bioeconomy comprises all economic activities where at least ten percent of the materials used are renewable. While this is a clear and operationalizable definition, there are two major drawbacks: 1. Ten percent seems like a rather arbitrary and weak benchmark. The authors provide no justification for their choice (see ibid., p. 38). In a related academic paper that outlines the methodological foundations of the report, the researchers used the ominous expression: 'The share of 10% was set as a result of review of the data in order to be operational' (Iost, Labonte, Banse et al. 2019, p. 276). If applied to the energy sector, for example, the benchmark would leave room for 90 percent non-sustainable, fossil energy and contradict the goals and principles of the bioeconomy. 2. In order to apply the ten percent criterion, information beyond the type of economic activity, like official statistics about material flows is necessary. Such data is often not easily available, incomplete and hardly comparable in an international context. However, here is what the report identifies for Germany as bioeconomic categories in NACE:

Fully bioeconomic are:

1) the complete section A (agriculture, forestry and fishing),
2) within section F (construction) the classes 43.32 'joinery installation' and the subclass 'carpentry and engineer timber construction' as part of the class 43.91 'roofing activities'[5],
3) the complete division 56 'food and beverage service activities',
4) the class 72.11 'research and experimental development on biotechnology'.

4 https://www.gesis.org/missy/files/documents/MZ/MZ2016_Erhebungsbogen.pdf, p. 13 [accessed 19.5.2021]

5 Subclasses are a type of category in the German classification of economic branches which is with one additional level of depth more detailed than NACE (Statistisches Bundesamt, 2008).

Partly assigned to the bioeconomy and therefor subject to further statistical assessment are the following economic activities:

1) In section C 'manufacturing' some activities are heavily bio-based such as the processing of food, timber and paper, others are hard to assess like textile or leather manufacture, still others have a very low bio-based share like the manufacture of petroleum or other chemical products. Because of the difficult data situation, the report suggests a 'fuzzy logic' approach measuring a minimum and maximum bio-based share for each economic activity. The actual bio-based share is assumed to be within this range (Bringezu et al. 2020, Iost et al. 2019).
2) In section D 'energy supply' economic activities are considered bio-based to a degree that equals the proportion of biomass in total energy sources.
3) Within section F 'construction' in the class 41.20 'construction of buildings' a timber construction quota is applied: The proportion of buildings mainly made from wood determines the degree to which this class is considered bio-based.
4) Economic activities in the class 72.19 'other research and experimental development on natural sciences and engineering' are considered to be bio-based to the degree that equals the rate of expenses for natural science and agricultural research.

All these solutions to measure a partly bio-based economic activity are not viable within the context of this work: The unit of interest here is jobs and if a category of economic activity is, for example, overall 45 percent bio-based, this doesn't give any information about a certain job in this category. Identifying the degree to which an activity is bio-based only makes sense in aggregate analyses but not at the individual level. Moreover, there are more groups and classes in NACE than the selected economic activities which may be considered to be part of the bioeconomy: In section E 'water and waste management', for instance, many steps in the economic process involve bio-based materials (microorganism cleaning water, organic waste etc.) and among all economic activities this section is perhaps most strongly based on the idea of a circular flow and the recycling of resources. Another example is within section F: The German bioeconomy monitoring only considers buildings but not bridges, railways and other constructions that may involve timber and other bio-based materials (Bringezu et al. 2020). Both examples are considered as parts of the bioeconomy by Kardung et al. (2021). Their approach, however, is also focused on measuring the bioeconomy from an aggregate perspective and consequently also uses estimations how bio-based an economic activity is depending on other data about the kind and degree of expenses, investments, materials and many more. With regard to the categories that are considered to be fully parts of the bioeconomy, the concept of Kardung et al. (2021) is largely in accordance with the German bioeconomy monitoring:

1) The complete section A,

2) divisions C10 (food products), C11 (beverages), C12 (tobacco products), C16

(wood and wood products), and C17 (paper and paper products),

3) I56 (food and beverage service activities).

From the huge body of concepts on how to measure the bioeconomy, a final look is taken at the categories suggested by the Joint Research Centre – Bioeconomics of the European Commission (Joint Research Centre 2020). This network of researchers uses similar estimations to the above-mentioned concepts to account for economic sectors that run only partly on bio-based materials and calculate, for example, the employment and the added value generated in these sectors. In 2017, 17.5 million persons worked in the bioeconomy in the EU27 (without UK), more than half of them were employed in agriculture (Ronzon, Piotrowski, Tamosiunas et al. 2020). This approach, however, focusses on production and includes only section A, the manufacture of fully or partly bio-based goods and bioenergy. Services as well as, research and development are not included.

In summary, some sectors can be identified which are always considered to be part of the bioeconomy. Conversely, a variety of sectors are not even partly regarded as bioeconomy. These are: The complete section B (mining and quarrying activities), various divisions, groups and classes in sections C, D, F and G, moreover the complete section H (transportation and storage), division 55 (accommodation) in section I and everything with a few exceptions like research in biotechnology from section J to U. Some categories that the various attempts to measure and monitor the bioeconomy do not consider as parts of the bioeconomy, are in fact, i.e. according to the definitions and criteria of the bioeconomy, at least partly, sometimes even fully, part of the bioeconomy. A borderline case, for example, is the extraction of peat (NACE class 08.92). Peat consists of more than ten percent of organic material that develops from dead plants in swamps and thus can be considered a bio-based/biological resource. Anyhow, it marks the first stage of the process of coalification and that may lead to peat being seen as a fossil resource. Further examples where current approaches missed to include unambiguously bio-based sectors can be found particularly in services: landscape services (81.3), botanical and zoological gardens and nature reserves activities (91.04), the repair of personal and household goods made from wood, textiles or leather (95.2), veterinary activities (75.0) or even running a camping ground (55.3).

As the goal of this work is to compare the social structure and working conditions between jobs in the bioeconomy with jobs in other kinds of economic activities, it seems useful to identify three categories of jobs: 1. fully bio-based jobs, 2. partly bio-based jobs and 3. jobs that are clearly not part of the bioeconomy (see Table 1). Working conditions and employment patterns can then be compared between these three categories. The decisions about the sectors are based on the examination of the concepts discussed above as well as the most broad definitions of the bioeconomy that

include not only the production and manufacturing of biomass but also service activities where the official description in the statistical classification of economic activities (EUROSTAT 2008) clearly mentions working with biological resources, life forms and bio-based goods.

Table 1: Categorization of economic activities as a) fully bioeconomic (green), b) partly bio-based (yellow) and c) not part of the bioeconomy (red), note: for better clarity the table doesn't show all NACE categories down to the forth level – subordinate categories have the same colour as their superordinate categories, only deviations are shown

A	1 Crop and animal production, hunting and related service activities
	2 Forestry and logging
	3 Fishing and aquaculture
B	5 Mining of coal and lignite
	6 Extraction of crude petroleum and natural gas
	7 Mining of metal ores
	8 Other mining and quarrying
	08.92 Extraction of peat
	9 Mining support service activities
C	10 Manufacture of food products
	11 Manufacture of beverages
	12 Manufacture of tobacco products
	13 Manufacture of textiles
	14 Manufacture of wearing apparel
	15 Manufacture of leather and related products
	16 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting ma
	17 Manufacture of paper and paper products
	18 Printing and reproduction of recorded media
	19 Manufacture of coke and refined petroleum products
	20 Manufacture of chemicals and chemical products
	21 Manufacture of basic pharmaceutical products and pharmaceutical preparations
	22 Manufacture of rubber and plastic products
	23 Manufacture of other non-metallic mineral products
	24 Manufacture of basic metals
	25 Manufacture of fabricated metal products, except machinery and equipment
	26 Manufacture of computer, electronic and optical products
	27 Manufacture of electrical equipment
	28 Manufacture of machinery and equipment n.e.c.
	29 Manufacture of motor vehicles, trailers and semi-trailers

	30 Manufacture of other transport equipment
	31 Manufacture of furniture
	32 Other manufacturing
	33 Repair and installation of machinery and equipment
D	35 Electricity, gas, steam and air conditioning supply
E	36 Water collection, treatment and supply
	37 Sewerage
	38 Waste collection, treatment and disposal activities; materials recovery
	39 Remediation activities and other waste management services
F	41 Construction of buildings
	42 Civil engineering
	43 Specialised construction activities
G	45 Wholesale and retail trade and repair of motor vehicles and motorcycles
	46 Wholesale trade, except of motor vehicles and motorcycles
	46.11 Agents involved in the sale of agricultural raw materials, live animals, textile raw materials and semi-finished goods
	46.12 Agents involved in the sale of fuels, ores, metals and industrial chemicals
	46.13 Agents involved in the sale of timber and building materials
	46.14 Agents involved in the sale of machinery, industrial equipment, ships and aircraft
	46.15 Agents involved in the sale of furniture, household goods, hardware and iron-mongery
	46.16 Agents involved in the sale of textiles, clothing, fur, footwear and leather goods
	46.17 Agents involved in the sale of food, beverages and tobacco
	46.18 Agents specialised in the sale of other particular products
	46.19 Agents involved in the sale of a variety of goods
	46.2 Wholesale of agricultural raw materials and live animals
	46.3 Wholesale of food, beverages and tobacco
	46.4 Wholesale of household goods
	46.5 Wholesale of information and communication equipment
	46.6 Wholesale of other machinery, equipment and supplies
	46.7 Other specialised wholesale
	46.9 Non-specialised wholesale trade
	47 Retail trade, except of motor vehicles and motorcycles
	47.1 Retail sale in non-specialised stores
	47.11 Retail sale in non-specialised stores with food, beverages or tobacco predominating
	47.2 Retail sale of food, beverages and tobacco in specialised stores
	47.3 Retail sale of automotive fuel in specialised stores
	47.4 Retail sale of information and communication equipment in specialised stores
	47.5 Retail sale of other household equipment in specialised stores

	47.6 Retail sale of cultural and recreation goods in specialised stores
	47.7 Retail sale of other goods in specialised stores
	47.76 Retail sale of flowers, plants, seeds, fertilisers, pet animals and pet food in specialised stores
	47.8 Retail sale via stalls and markets
	47.81 Retail sale via stalls and markets of food, beverages and tobacco products
	47.9 Retail trade not in stores, stalls or markets
H	49 Land transport and transport via pipelines
	50 Water transport
	51 Air transport
	52 Warehousing and support activities for transportation
	53 Postal and courier activities
I	55 Accommodation
	55.3 Camping grounds
	56 Food and beverage service activities
J	58 Publishing activities
	59 Motion picture, video and television programme production, sound recording and music publishing activities
	60 Programming and broadcasting activities
	61 Telecommunications
	62 Computer programming, consultancy and related activities
	63 Information service activities
K	64 Financial service activities, except insurance and pension funding
	65 Insurance, reinsurance and pension funding, except compulsory social security
	66 Activities auxiliary to financial services and insurance activities
L	68 Real estate activities
M	69 Legal and accounting activities
	70 Activities of head offices; management consultancy activities
	71 Architectural and engineering activities; technical testing and analysis
	72 Scientific research and development
	72.11 Research and experimental development on biotechnology
	73 Advertising and market research
	74 Other professional, scientific and technical activities
	75 Veterinary activities
N	77 Rental and leasing activities
	78 Employment activities
	79 Travel agency, tour operator and other reservation service and related activities
	80 Security and investigation activities
	81 Services to buildings and landscape activities

	81.3 Landscape service activities
	82 Office administrative, office support and other business support activities
O	84 Public administration and defence; compulsory social security
P	85 Education
Q	86 Human health activities
	87 Residential care activities
	88 Social work activities without accommodation
R	90 Creative, arts and entertainment activities
	91 Libraries, archives, museums and other cultural activities
	91.04 Botanical and zoological gardens and nature reserves activities
	92 Gambling and betting activities
	93 Sports activities and amusement and recreation activities
S	94 Activities of membership organisations
	95 Repair of computers and personal and household goods
	95.2 Repair of personal and household goods
	96 Other personal service activities
T	97 Activities of households as employers of domestic personnel
	98 Undifferentiated goods- and services-producing activities of private households for own use
U	99 Activities of extraterritorial organisations and bodies

2.2. Assessing Jobs in the Bioeconomy with Data from the European Union Labour Force Survey

The EU-LFS contains comprehensive information about employment and jobs of large representative samples of the population of EU countries. The data is collected through national surveys and then compiled by EUROSTAT where the data is also processed according to international standards and then published and distributed in reduced, less complex format. The scientific use files, which can be received by researchers after a formal application process, are subject to very strict security measures and restrictions to ensure anonymity and informational autonomy of respondents. For this purpose, a range of variables contains only partial information and unfortunately this applies particularly to the variable measuring the type of economic activity (NACE). Just the first digit of the complete categorization is available, hence only sections can be differentiated and no further differentiation into groups, classes and divisions is possible. For the goal of measuring the bioeconomy this means merely section A 'agriculture, forestry and fishing' can be unambiguously identified as fully bioeconomic. Therefore, in Table 2 the tripartite categorization of economic activities needs to be simplified, sections B (mining) and E (water, sewerage, waste) are, for the purpose of this paper, henceforth not considered a part of the bioeconomy like in

most other measurement concepts of the bioeconomy.

Table 2: Categorization of jobs as a) fully bioeconomic (green), b) partly bio-based (yellow) and c) not part of the bioeconomy (red) based on the one-digit NACE within the EU-LFS

NACE section	Details
A (agriculture, forestry, fishing)	
B (mining, quarrying)	Peat is neglected
C (manufacturing)	Food, beverages, tobacco, wood and paper are bioeconomy
D (electricity, gas)	Energy from biomass is part of bioeconomy
E (water, sewerage, waste)	Organic waste is neglected
F (construction)	Construction with wood is bioeconomy
G (wholesale, retail)	Trading with plants, animals, food, beverages and tobacco is bioeconomy
H (transportation, storage)	
I (accommodation, food service)	Food and beverages are part of the bioeconomy
J (information, communication)	
K (financial, insurances)	
L (real estate)	
M (prof., scientific, technical act.)	Biotech research and veterinary activities belong to the bioeconomy
N (administration, support service)	Landscape activities belong to the bioeconomy
O (public administration, defence)	
P (education)	
Q (health, social work)	
R (arts, entertainment, recreation)	Botanical and zoological gardens are part of bioeconomy
S (other service)	
T (households)	
U (extraterritorial organizations)	

In order to identify bioeconomy jobs within the yellow sections (partly bio-based) additional information beyond the type of economic activity is needed. Here data on occupations can be utilized: They are categorized in a standardized system similar to what NACE is for the type of economic activity. The latest version of the international standard classification of occupations (ISCO-08) organizes occupations hierarchically in categories on four levels and assigns them a four-digit code (International Labour Organisation 2012). In most social surveys, like in the EU-LFS, the exact occupational category is assessed by asking at least two questions: one about the name

of the current occupation and the area in which the respondents work (for example: teacher in a secondary school or tradesperson in a retail shop) and the second about the training requirements for this occupation (for instance: Bachelor from university, or occupational training)[6]. In Table 3 bioeconomy occupations are shown: they mainly are occupations typical for agriculture, the food sector, manufacturing and trade with bio-based materials. The selection is again the result of assessing the descriptions (International Labour Organisation 2012) of all occupations classified within ISCO-08 according to the criteria that the occupation usually involves working with biological materials or living organisms (except humans[7]) and comprises production, manufacturing and services as well.

Table 3: Bio-based occupations (own qualitative assessment)

ISCO-08 code	Title of occupation
131	Production managers in agriculture, forestry and fisheries
1311	Agricultural and forestry production managers
1312	Aquaculture and fisheries production managers
213	Life science professionals
2131	Biologists, botanists, zoologists and related professionals
2132	Farming, forestry and fisheries advisers
2133	Environmental protection professionals
225	Veterinarians
314	Life science technicians and related associate professionals
3141	Life science technicians (excluding medical)
3142	Agricultural technicians
3143	Forestry technicians
512	Cooks
5120	Cooks
513	Waiters and bartenders
5131	Waiters
5132	Bartenders
6	Skilled agricultural, forestry and fishery workers
61	Market-oriented skilled agricultural workers

6 See for example: https://www.gesis.org/missy/files/documents/MZ/MZ2016_Erhebungsbogen.pdf, p. 11 [accessed 19.5.2021]

7 The question why working with humans is not regarded as bioeconomic activity, even in the case of medical doctors, may point to the fact that much of the research on the bioeconomy is subject to the largely ignored axiom of a naturalist human-nature divide: although humans are organic they are not nature and thus do not belong to the bioeconomy.

611	Market gardeners and crop growers
6111	Field crop and vegetable growers
6112	Tree and shrub crop growers
6113	Gardeners, horticultural and nursery growers
6114	Mixed crop growers
612	Animal producers
6121	Livestock and dairy producers
6122	Poultry producers
6123	Apiarists and sericulturists
6129	Animal producers not elsewhere classified
613	Mixed crop and animal producers
6130	Mixed crop and animal producers
62	Market-oriented skilled forestry, fishery and hunting workers
621	Forestry and related workers
6210	Forestry and related workers
622	Fishery workers, hunters and trappers
6221	Aquaculture workers
6222	Inland and coastal waters fishery workers
6223	Deep-sea fishery workers
6224	Hunters and trappers
63	Subsistence farmers, fishers, hunters and gatherers
631	Subsistence crop farmers
6310	Subsistence crop farmers
632	Subsistence livestock farmers
6320	Subsistence livestock farmers
633	Subsistence mixed crop and livestock farmers
6330	Subsistence mixed crop and livestock farmers
634	Subsistence fishers, hunters, trappers and gatherers
6340	Subsistence fishers, hunters, trappers and gatherers
732	Printing trades workers
7321	Pre-press technicians
7322	Printers
7323	Print finishing and binding workers
75	Food processing, wood working, garment and other craft and related trades workers
751	Food processing and related trades workers
7511	Butchers, fishmongers and related food preparers
7512	Bakers, pastry-cooks and confectionery makers
7513	Dairy-products makers

7514	Fruit, vegetable and related preservers
7515	Food and beverage tasters and graders
7516	Tobacco preparers and tobacco products makers
752	Wood treaters, cabinet-makers and related trades workers
7521	Wood treaters
7522	Cabinet-makers and related workers
7523	Woodworking-machine tool setters and operators
816	Food and related products machine operators
8160	Food and related products machine operators
817	Wood processing and papermaking plant operators
8171	Pulp and papermaking plant operators
8172	Wood processing plant operators
92	Agricultural, forestry and fishery labourers
921	Agricultural, forestry and fishery labourers
9211	Crop farm labourers
9212	Livestock farm labourers
9213	Mixed crop and livestock farm labourers
9214	Garden and horticultural labourers
9215	Forestry labourers
9216	Fishery and aquaculture labourers
94	Food preparation assistants
941	Food preparation assistants
9411	Fast food preparers
9412	Kitchen helpers

Data anonymization efforts in the EU-LFS also affect the ISCO-08 variable, but in this case only the last digit is deleted, so a three-digit code can be used to identify occupations in the bioeconomy. It is possible to unambiguously identify occupations that are bio-based – a category which collects unclear cases is thus not necessary. Now a cross-tabulation between the type of economic activity (NACE) and occupation (ISCO) can be applied to classify jobs as belonging to the bioeconomy, belonging partly to it or not at all (see Table 4).

Table 4: Typology of jobs in the bioeconomy

Type of economic activity/ occupation	Sector belongs fully to the bio-economy	Sector belongs partly to the bio-economy	Sector does not belong to the bioeconomy
Bio-based occupation	Job in the core bioeconomy	Job in the wider bioeconomy	Unclear
Not bio-based occupation	Job in the wider bioeconomy	Unclear	Job outside the bioeconomy

The cross-tabulation leads to a quadripartite typology of jobs: If both sector and occupation are clearly bio-based, the job can be considered to belong to what is here termed as the **core bioeconomy**. If either sector or occupation is clearly bio-based and the other at least partly considered to be part of the bioeconomy, the job is in what is understood as the **wider bioeconomy**. If both, sector and occupation are clearly not part of the bioeconomy, the job is consequently seen as **outside of the bioeconomy**. In the fourth case, only sector or occupation are partly bio-based while the other is outside the bioeconomy. Here it cannot be decided whether or to which degree the job is in the bioeconomy, hence these cases are labelled **unclear** and treated as separate category in the analyses.

Example: A veterinarian (ISCO-08: 225) would be part of the core bioeconomy if she works in agriculture (NACE: A). She would be assigned to the wider bioeconomy in case she works in a circus caring for the animals (NACE: R) and she would fall in the unclear category if she would work as a teacher at a school (NACE: P).

Compared to other measurement concepts this typology of jobs in the bioeconomy is, on the one hand, very inclusive, as it a) also includes bio-based services and b) integrates cases in the wider bioeconomy that would be left out if only sectors would be considered. On the other hand, the category of the core bioeconomy is very restrictive/exclusive as both occupation and sector have to fulfil the criteria. Depending on the focus of the study, comparisons can be conducted between the core bioeconomy and non-bio-based jobs or between all three job categories. In case data is even more restricted than in the EU-LFS and occupation is also only available through one or two digits, the typology can be expanded to a 3x3 cross table with the additional category 'partly bio-based occupation' (see Table 5).

Table 5: Extending the typology of jobs in the bioeconomy

Type of economic activity/ occupation	Fully bio-based sector	Partly bio-based sector	Not bio-based sector
Fully bio-based occupation	Core bioeconomy	Wider bioeconomy	Unclear
Partly bio-based occupation			
Not bio-based occupation			Outside bioeconomy

3. The Finnish Bioeconomy in 2018

As an example of how to apply the above described approach, the following sections present analyses of the bioeconomy in Finland in the year 2018 using data from the EU-LFS. In the first part, the social structure of the Finnish bioeconomy is investigated with regard to age, gender, education, country of birth and region. The second part deals with the working conditions and assesses occupational class, employment status, work contracts and the working hours of persons working in the bioeconomy.

3.1. Social Structure of the Bioeconomy in Finland

According to the EUROSTAT definition: '*The labour force or workforce or economically active population, also shortened to active population, includes both employed (employees and self-employed) and unemployed people, but not the economically inactive, such as pre-school children, school children, students and pensioners*[8]', the labour force is used here as the reference group. In the year 2018 nearly half of the Finnish population was part of the labour force, three percent of the population were unemployed (this equals 6.3 percent of the labour force), one-third economically inactive (e.g. students or pensioners) and 17 percent were children below the age of 15 years (Table 6).

Table 6: The labour force in Finland 2018

	Frequency in EU-LFS sample	Percent
Labour force / workforce		
Employed (incl. self-employed)	21,981	46.1
Unemployed	1,478	3.1
Inactive	15,735	33.0
Compulsory military service	223	0.5
Child	8,258	17.3
Total	47,675	100.0

How many people from the labour force worked in the bioeconomy? The data from the EU-LFS only allows for a rough estimation because many respondents either gave no answer when asked about their occupation and type of economic activity or their answers could not be classified or they even weren't asked these questions. Consequently, the proportion of missing values is very high: from the more than 23,000 respondents within the labour force only 12,000 have valid values for occupation and type of economic activity (see Table 7). Since there is no information about the reasons why for so many respondents valid answers do not exist, the data does not' allow for representative statements about the Finnish labour force. It is, however, possible to take a closer look into the social structure of those who gave valid answers. Three percent of them hold a job in the core bioeconomy, i.e. both their occupation and their type of economic activity can be clearly identified as part of the bioeconomy.

8 https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Labour_force [accessed: 03.03.2021]

Another 5.5 percent work in the wider bioeconomy and 45 percent have jobs that are completely outside the bioeconomy.

Table 7: Bio-based employment in the Finnish labour force 2018

	Frequency in EU-LFS sample	Percent
Core bioeconomy	370	3.1
Wider bioeconomy	663	5.5
Unclear	5,579	46.3
Outside bioeconomy	5,428	45.1
Valid total	12,040	100.0
Missing	11,419	
Total	23,459	

Regarding economic sectors, jobs in the bioeconomy are – unsurprisingly – most widespread in agriculture, forestry and fishing (see Table 8). All employees in this sector either work in the core or in the wider bioeconomy. The second most important bioeconomy sector is accommodation and food service where two-thirds of the employees work in the wider bioeconomy. About twelve percent of the persons employed in manufacturing are working with bio-based materials, thus belong to the wider bioeconomy. Smaller proportions exist in several other sectors, for example, in 'wholesale and retail' where about two percent of the employees are trading with bio-based products and in 'professional, scientific and technical activities' where five percent of the employees can be assigned to the wider bioeconomy and where research and development in the high-tech bioeconomy is taking place.

Table 8: Bio-based economic sectors in Finland 2018

	Share of employed persons	
Economic sector (NACE)	Core bioeconomy	Wider bioeconomy
A (agriculture, forestry, fishing)	83.4	16.6
C (manufacturing)	0.0	12.2
D (electricity, gas)	0.0	2.7
F (construction)	0.0	1.5
G (wholesale, retail)	0.0	2.4
I (accommodation, food service)	0.0	67.2
M (prof., scientific, technical act.)	0.0	5.0
N (administration, support service)	0.0	4.7
R (arts, entertainment, recreation)	0.0	2.0

The bioeconomy in Finland is a predominantly male shaped field, particularly in the core bioeconomy where 70 percent of employees are men (Table 9). In contrast, only 38 percent of the jobs outside the bioeconomy are held by men.

Table 9: Distribution of women and men in the bioeconomy, Finland 2018

Sex	Core bio-economy	Wider bio-economy	Unclear	Outside bioeconomy	Total
Male	71.1	50.2	62.6	38.2	51.2
Female	28.9	49.8	37.4	61.8	48.8

Working in the core bioeconomy is associated with older age, the median age in this sector is 52 years compared to 42 years in the wider bioeconomy and among all sectors (Figure 4). The differences between the average ages of the employees within the core bioeconomy and the other groups are highly significant ($p<0.001$). Because of the high amount of missing information about economic sectors and occupations in the Finnish data, it is, however, uncertain whether the result of age differences between the core bioeconomy and other sectors is valid also for the total workforce. Similar findings for Germany (see below), where nearly complete information is given, suggests that this is very likely the case.

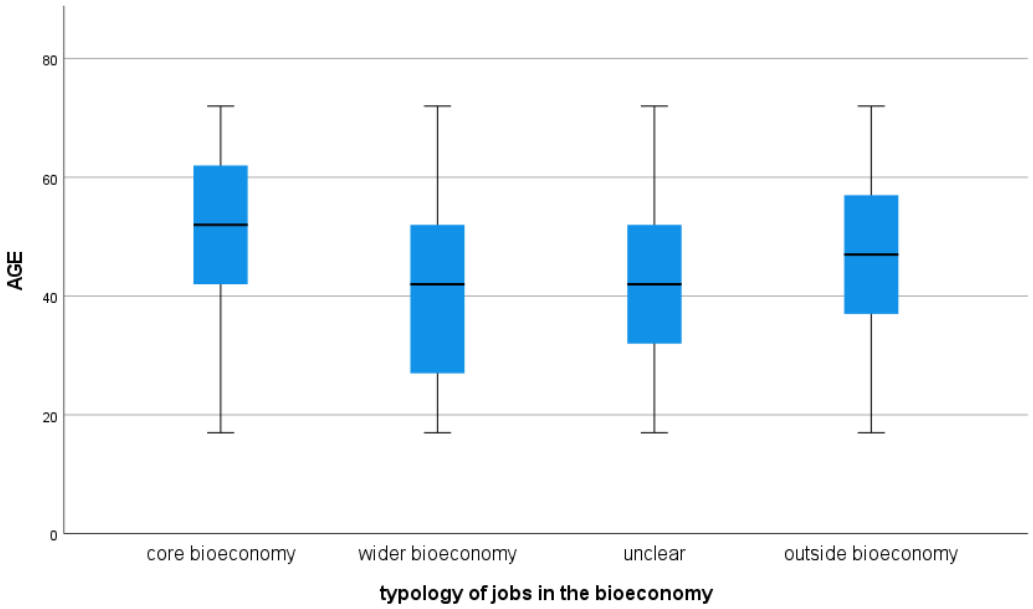

Figure 4: Age in the Finnish bioeconomy 2018

As Table 10 reveals, employees in the core bioeconomy tend to hold lower educational degrees than the average of the labour force. Nearly ten percent only finished

primary school, compared to two percent in the total labour force. About 15 percent hold a Bachelor or higher degree in the core bioeconomy while this is the case for more than 30 percent of the total labour force. Moreover, working in the wider bioeconomy is also linked with below average educational degrees while holding a job outside the bioeconomy is related with higher educational degrees.

Table 10: Levels of education in the bioeconomy, Finland 2018

Level of education	Core bioeconomy	Wider bioeconomy	Unclear	Outside bioeconomy	Total
Primary education	9.7	3.0	1.5	1.1	1.7
Lower secondary education	13.2	14.6	12.0	5.4	9.2
Upper secondary education	51.4	61.8	47.2	36.7	43.4
Post-sec. non-tertiary education	1.1	2.0	1.3	1.0	1.2
Short-cycle tertiary education	10.3	5.3	10.1	13.9	11.6
Bachelor's or equivalent level	9.2	7.5	15.7	19.5	16.8
Master's or equivalent level	4.9	4.4	11.1	20.4	14.7
Doctoral or equivalent level	0.3	1.4	1.0	2.0	1.4

Considering that jobs in the bioeconomy are most widespread in agriculture and forestry and linked with lower education, it could be assumed that incomes are below average, because most well-paid jobs require higher educational degrees and are in others than the primary sector. However, this assumption cannot be tested as there is no data on income about the respondents of the Finnish Labour Force Survey in 2018 (there is data on income for Germany, see next chapter).

The question to what extent the bioeconomy in Finland is characterized by seasonal workers and workers from abroad can at least partially be answered with the data at hand: First, seasonal work done by persons who come from abroad, work for a couple of weeks, for example, in harvesting crops or fruits, and then travelling back to their home countries, is not covered by the EU-LFS as the survey is targeted at the resident population of the participating countries. This includes persons who stay at least one year in the country (European Commission 2018). Second, the respondents are, however, asked about their nationality and country of birth and this information reveals a somewhat double-edged structure of the bioeconomy in Finland (see Table 11). The share of persons born in Finland as well as of those with Finnish nationality working in the core bioeconomy is higher than in the total workforce. The differences are small but statistically highly significant ($p<0.001$). This means jobs in agriculture, forestry and fishing are held mainly by Finnish persons, immigrants are very rare (seasonal work like berry picking in the forests exempted). By contrast, persons who work

in the wider bioeconomy hold significantly more often a nationality other than the Finnish and are born more frequently outside of Finland. It can be assumed that this pattern is due to the high weight of the food and beverages service activities within the wider bioeconomy. Workers in this sector, which includes, for example, restaurants and cafes, more often have a migrant history (7.9 percent) as those in other sectors (2.9 percent).

Table 11: Nationality and country of birth in the bioeconomy, Finland 2018

	Core bioeconomy	Wider bioeconomy	Unclear	Outside bioeconomy	Total
Nationality					
Finnish	98.1	94.3	96.9	97.6	97.1
Other	1.9	5.7	3.1	2.4	2.9
Country of Birth					
Finland	96.8	91.3	94.2	95.0	94.5
Other	3.2	8.7	5.8	5.0	5.5

Jobs in the bioeconomy in Finland are most widespread in more rural regions. For example, in the largest region 'Pohjois- ja Itä-Suomi' (FI 1D), covering more than half the country's area, more than five percent of the workforce is working in the core bioeconomy and another 6.4 percent in the wider bioeconomy. In the more urban region around the capital Helsinki (FI 1B), only few people work in the bioeconomy: half a percent in the core bioeconomy and nearly four percent in the wider bioeconomy (see Figure 5). Overall, three out of four persons employed in the core bioeconomy live in rural areas, only seven percent in cities (Table 12). In contrast, from the persons working in non-bioeconomy jobs only every forth lives in rural surroundings while more than forty percent live in densely populated cities. These statistics again indicate that most employment in the bioeconomy is in the primary sector and less so in other sectors like including biotechnology and research.

Table 12: Degree of urbanization and the bioeconomy, Finland 2018

Urbanisation	Core bioeconomy	Wider bioeconomy	Unclear	Outside bioeconomy	Total
Cities	7.0	28.2	39.1	42.4	39.0
Towns and suburbs	20.0	35.9	32.6	31.2	31.8
Rural area	73.0	35.9	28.3	26.3	29.2

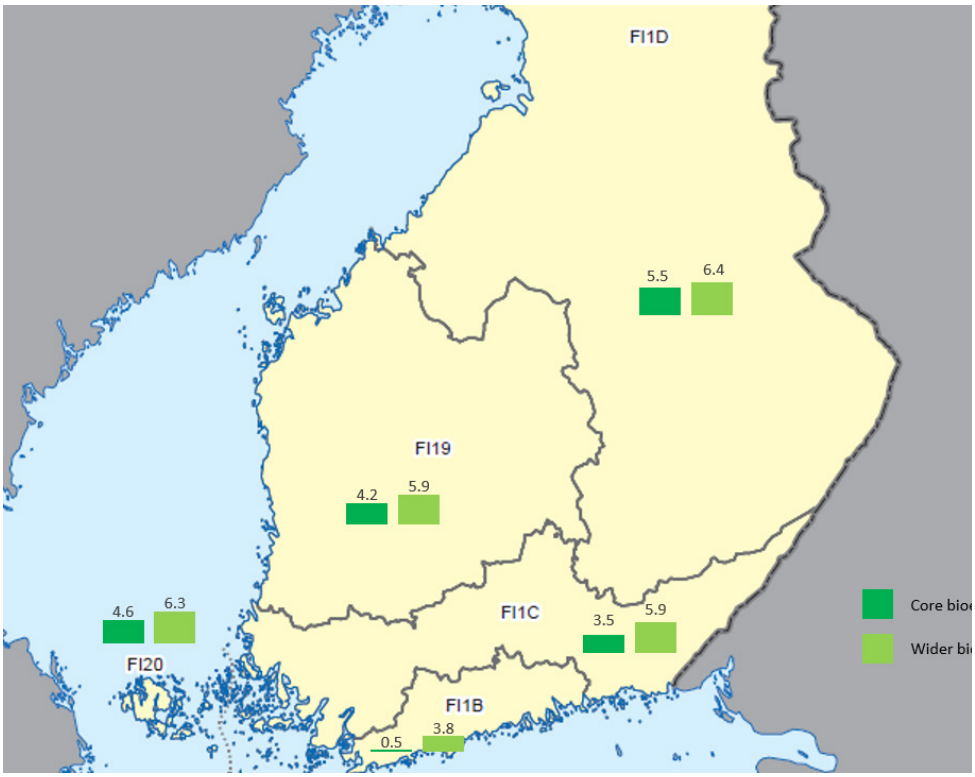

Figure 5: Share of bio-based jobs in regions of Finland 2018 (percent of total workforce)

3.2. Working Conditions

In this section the Finnish bioeconomy is examined with regard to the working conditions that people experience in bio-based jobs vs. those in jobs outside the bioeconomy: Which occupational classes are shaped by bio-based economic activities, what type of work contracts prevail, what are the usual working hours, how frequent is self-employment and atypical work, etc.?

Table 13: Occupational structure of the bioeconomy in Finland 2018

	Core bio-economy	Wider bioecon-omy	Unclear	Outside bioecon-omy	Total
Occupational classes[9]					
Higher-grade service class	3.3	7.7	20.9	27.7	22.7
Lower-grade service class	0.8	5.8	16.1	29.3	21.0
Small business owners	74.9	10.7	11.8	5.7	11.0
Skilled workers	1.9	19.2	17.2	14.3	15.5
Unskilled workers	19.1	56.6	34.1	22.9	29.7
Professional status					
Self-employed	66.0	11.2	14.8	7.4	12.9
Employee	24.9	87.8	84.9	92.4	86.6
Family worker	9.1	1.0	0.2	0.2	0.5

With a share of three quarters the core bioeconomy in Finland is dominated by small business owners, an occupational class that, among others, contains farmers who run their own agricultural businesses. Unskilled workers in the core bioeconomy make up for another 20 percent which is a surprising low value compared to the 30 percent that unskilled workers provide in the total workforce (Table 13). Self-employment and working in a family business are much more common in the core bioeconomy than anywhere else in the economy, while the share of regular employees is exceptionally low. These results indicate that the primary sector in Finland is shaped by small family businesses who mostly do not hire workers from the labour market. Most of the work is done with the help of technology and machines, it is a high-tech bioeconomy that does not need much human labour and thus does not create many jobs. Things look different in the wider bioeconomy that includes food service activities as its largest part. Here, the share of unskilled workers is very high, more than half of

9 In order to explore occupations in the bioeconomy, occupational classes were operationalized according to Oesch, Daniel. 2006. *Redrawing the Class Map. Stratification and Institutions in Britain,* Germany, Sweden and Switzerland. Basingstoke: Palgrave Macmillan.. Based on the required skill level and the work logic of an occupation, this approach classifies occupations into 16 occupational classes. The above used five categories are a summary of these suggested by Oesch. The two service classes contain occupations with administrative and interpersonal work logic, distinguished by the skill level the occupation requires (high or low). The class of small business owners contains self-employed persons who perform within an independent work logic. Finally, the group of workers is divided in two classes based on the required skill level and is associated with a technical work logic.

the workers in the wider bioeconomy belong to this group. This part of the bioeconomy is characterized by a high number of jobs requiring low skill levels such as in the case of waiters or support staff in the kitchen.

Are there any specific patterns regarding the existence of non-standard employment (Koch and Fritz 2013) in the bioeconomy? Self-employment, as one of the three most common types of non-standard or atypical work, is widespread particularly in the core bioeconomy – how about the other two types: temporary work contracts (contracts with limited duration) and part-time work? As Table 14 shows, both types of atypical work do occur more often in the core and wider bioeconomy than in the total workforce. Nearly one quarter of the employees in the core bioeconomy have contracts with limited duration (compared to every sixth person in the total workforce) and even more, about 28 percent of all workers in the core bioeconomy including those that are self-employed, work in part-time. In the wider bioeconomy both types of atypical work are a bit less common but still clearly above the average. Another type of non-standard work, which is less widespread among European labour markets, are second jobs that people hold besides their main jobs. Even this kind of atypical work is significantly more frequent in the core bioeconomy (but not in the wider bioeconomy): About ten percent of the core bioeconomy workers report to have another than their main job (e.g. an agricultural worker who works as a waiter at the weekend).

Table 14: Non-standard employment in the bioeconomy in Finland 2018

	Core bio-economy	Wider bio-economy	Unclear	Outside bioeconomy	Total
Permanent	76.1	80.9	86.7	81.9	84.0
Temporary	23.9	19.1	13.3	18.1	16.0
Full-time	72.5	77.3	83.1	85.2	83.4
Part-time	27.5	22.7	16.9	14.8	16.6
Second job	9.7	5.6	4.7	6.6	5.8

All these details point to the conclusion that jobs in the bioeconomy are less standardized than other jobs. This may be caused by the nature of bio-based resources, products and processes which require timely treatment and can be rationalized, normed and planned to a much lesser degree than non-living, non-organic stuff. More evidence for this argument is finally provided by a more detailed look at the occurrence and distribution of working hours. Atypical working hours can occur in the form of shift work, work in the evening, at night, on Saturday and on Sunday. Respondents in the European Labour Force Survey were asked whether they usually, sometimes or never experience each of these five forms.

Table 15: Atypical working hours in the bioeconomy in Finland 2018 (cumulated shares for 'usually' and 'sometimes')

Usually or sometimes:	Core bioeconomy	Wider bioeconomy	Unclear	Outside bioeconomy	Total
Shift work	12.2	45.0	20.1	23.5	23.0
Evenings	63.1	56.4	45.5	49.5	48.4
Nights	21.9	28.2	10.5	16.7	14.6
Saturdays	75.6	49.2	35.1	36.3	37.7
Sundays	63.2	38.7	22.9	30.1	28.3

The differences between jobs in the bioeconomy and non-bioeconomy jobs are striking: While the share of people experiencing shift work is lower than average in the core bioeconomy, it is, probably due to food and beverage service activities, much higher in the wider bioeconomy where nearly half of the workers usually works in shifts[10] (Table 15). Working in the evenings is quite common in the Finnish world of work with every second worker reporting to do so at least sometimes. It is, however, even more common among workers in the bioeconomy. In the core bioeconomy more than 60 percent also work in the evenings and in the wider bioeconomy 56 percent compared to 48 percent in the total workforce. While 15 percent of the Finnish workers hold jobs that involve working at nights, this applies to 22 percent of workers in the core bioeconomy and 28 percent in the wider bioeconomy (bars, restaurants and clubs are open at night). Both the core and the wider bioeconomy include comparatively very high shares of jobs that require working at the weekend, the top value here are the more than 75 percent of workers in the core bioeconomy who regularly work on Saturdays. Also, in the wider bioeconomy working at weekends is clearly more frequent than on average.

In summary, working conditions, particularly working hours, are highly unstandardized in the Finnish bioeconomy as compared to the 'rest' of economic sectors. Thereby some differences exist between the core bioeconomy and the wider bioeconomy which is shaped strongly by food and beverage service activities and less so by agriculture and the manufacture of bio-based resources: The first is characterized by very high proportions of self-employment, small family businesses, non-standard forms of contracts like temporary employment, part-time work and second jobs as well as working hours that occur when other workers enjoy their free time: in the evenings and at the weekends. The latter is similar insofar as non-standardization is also higher than in non-bioeconomy sectors but has, in contrast, the highest shares of unskilled

10 The category sometimes is 'empty' for this variable because there is no change between working shifts and not working shifts, there are no jobs where people sometimes work shifts and sometimes work always at the same times.

workers within the total labour force. Moreover, working shifts and during the night is most common here.

4. The Bioeconomy in Germany 2018

The first two sections in this chapter deal with the social structure and working conditions in the German bioeconomy similarly as in the previous chapter about Finland. The findings are discussed in comparison to Finland. The last section focuses on trends within the German bioeconomy and contrasts the findings with the results of the German bioeconomy monitoring (Bringezu et al. 2020).

4.1. Social Structure

Looking at the size of the German labour force in the year 2018, we see that just above half of the population is either employed or self-employed while unemployment as percentage of the total population is low at 1.7 percent (Table 16). This equals an unemployment rate (unemployed as share of the labour force) of 3.2 percent. Compared to Finland the share of persons in the labour force is higher in Germany, one reason for this may be that there are relatively more children in the Nordic country. The category 'compulsory military service' doesn't exist for Germany as it was suspended in 2011.

Table 16: The labour force in Germany 2018

	Frequency in EU-LFS sample	Percent
Labour force / workforce		
Employed (incl. self-employed)	268,153	50.9
Unemployed	8,789	1.7
Inactive	179,759	34.1
Child	69,816	13.3
Total	526,517	100.0

The employed and unemployed persons constituting the labour force are the basis for the following statistics, inactive persons and children are not included.

In contrast to the Finnish LFS data where there is no valid information about the occupations or economic sectors for half of the respondents, information about the bioeconomy for Germany is almost complete, only about one percent could not be classified. According to the numbers in Table 17, the core bioeconomy in Germany is very small in terms of persons working there. Only one percent of the labour force

holds a job in this sector – the higher number in Finland (3.1 percent) is probably due to the greater importance of the forestry sector. Also, jobs in the wider bioeconomy are less prevalent in Germany than in Finland, but the difference is small and does not suggest any structural reasons explaining it (4.8 compared to 5.5 percent). About 40 percent of persons in the labour force work outside the bioeconomy, meaning neither their occupation is assigned to the bioeconomy nor the economic sector in which they are (self-)employed.

Table 17: Bio-based employment in the German labour force 2018

	Frequency in EU-LFS sample	Percent
Core bioeconomy	2,680	1.0
Wider bioeconomy	13,141	4.8
Unclear	144,376	52.7
Outside bioeconomy	113,989	41.6
Valid total	274,186	100.0
Missing	2,756	
Total	276,942	

The breakdown of persons working in the core and wider bioeconomy by economic sectors in Germany reveals a similar picture as in Finland. The sectors with the highest shares of workers in the bioeconomy are agriculture, forestry, and fishing as well as accommodation and food service activities. While in the first sector three quarters of the respondents belong to the core bioeconomy, i.e. they not only work in sector 'A' but also have a bio-based occupation, more than half of the workers in the latter sector are part of the wider bioeconomy (Table 18). In direct comparison both figures are lower in Germany than in Finland: 76 percent compared to 83 for the agricultural sector and 54 percent compared to 67 for accommodation and food. This could indicate a greater heterogeneity of occupations within the two sectors in Germany.

Table 18: Bio-based economic sectors in Germany 2018

	Share of employed persons in economic sectors who are in the bioeconomy	
Economic sector (NACE)	Core bioeconomy	Wider bioeconomy
A (agriculture, forestry, fishing)	76.0	24.0
C (manufacturing)	0.0	5.2
D (electricity, gas)	0.0	1.1

F (construction)	0.0	5.1
G (wholesale, retail)	0.0	2.5
I (accommodation, food service)	0.0	53.7
M (prof., scientific, technical act.)	0.0	3.8
N (administration, support service)	0.0	9.7
R (arts, entertainment, recreation)	0.0	8.3

Other economic sectors with significant shares of persons working in the wider bioeconomy are administration and support service activities with nearly ten percent. This is more than twice as much as in Finland. Whether the reason is a particularly high employment in and importance of landscape service activities in Germany – the only bio-based activities within this sector – remains unclear and could be studied in further analyses. Also, relatively high portions of bio-based work are found in the sector 'arts, entertainment and recreation' (about eight percent), manufacturing and construction both feature about five percent, and small fractions of bio-based work exist in section G 'wholesale and retail' (2.5 percent) and the energy sector (one percent). High hopes are placed in biotechnology and research of bio-based innovations. In the according economic sector of professional, scientific and technical activities, however, only about four percent of the workers are dealing with bio-based materials. In Finland this figure is slightly higher with five percent.

Similarly to the situation in Finland, the gender distribution of the bioeconomy in Germany is biased towards men with almost three out of four persons working in the core bioeconomy being males (Table 19). In contrast to the Nordic country the relative surplus of men also exists in the wider bioeconomy. Women work more frequently outside the bioeconomy.

Table 19: Distribution of women and men in the bioeconomy, Germany 2018

Sex	Core bio-economy	Wider bio-economy	Unclear	Outside bioeconomy	Total
Male	73.7	57.9	61.5	41.3	53.0
Female	26.3	42.1	38.5	58.7	47.0

Another commonality of the German and Finnish bioeconomy is the age structure: Workers in the German bioeconomy are on average 48 years old which is significantly older than persons working outside the bioeconomy whose mean age is 44 (Figure 6). Also, in both countries the youngest workers are in the wider bioeconomy, where the predominating sector of accommodation and food services includes high shares of young persons that work temporarily in restaurants and bars.

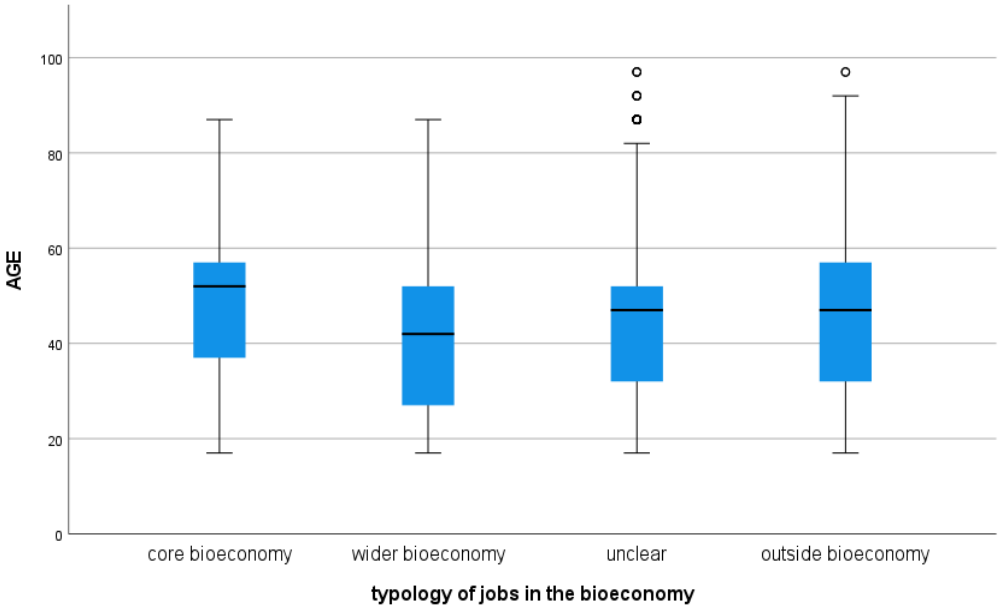

Figure 6: Age in the German bioeconomy 2018

Workers in the German bioeconomy in general hold lower educational degrees than persons working outside the bioeconomy. But the situation in Germany is somewhat different from the one in Finland. First, the two lowest degrees (see Table 20) 'primary and lower secondary education' are not more frequent among workers in the core bioeconomy than in the whole labour force. In contrast, these educational degrees are much more widespread in the wider bioeconomy, including the accommodation and food sector with a lot of temporary workers. The three highest educational degrees are clearly more seldom on both the core and the wider bioeconomy, with the exception of the Bachelor degree which is nearly as common in the core bioeconomy as the total economy. A special case marks the 5th educational degree 'short-cycle tertiary education' which includes more practically-based programmes that are more complex than usual occupationally-specific programs but shorter and less theoretical than Bachelor's programs. The typical German apprenticeship as master craftsman/foreman falls into this category and is way more frequent in the core bioeconomy (more than 9 percent) where the apprenticeship as farmer is often followed by a master's specialization in a field like poultry or cattle farming. This peculiarity of the German educational system (connected to the dual system) and the high professionalization of the German agriculture provide for smaller educational differences between the bioeconomy and the non-bio-based sectors of the economy than in Finland.

Table 20: Levels of education in the bioeconomy, Germany 2018

Level of education	Core bio-economy	Wider bioecon-omy	Unclear	Outside bioecon-omy	Total
Primary education	2.0	6.0	2.2	1.6	2.2
Lower secondary education	11.5	18.8	11.3	7.3	10.0
Upper secondary education	55.6	55.4	50.3	38.6	45.7
Post-sec. non-tertiary education	4.4	7.8	9.7	16.5	12.4
Short-cycle tertiary education	9.4	0.8	0.4	0.6	0.6
Bachelor's or equivalent level	13.3	6.3	15.9	16.7	15.8
Master's or equivalent level	3.6	4.0	9.1	16.2	11.7
Doctoral or equivalent level	0.2	1.0	1.0	2.5	1.6

In the chapter on Finland it was assumed that due to the on average lower educational attainments income could be lower in the bioeconomy than elsewhere in the economy. While this could not be tested for the case of Finland as data on income was missing, this information is available for Germany. If the persons in the sample of the LFS are ranked according to their income (here: monthly take home pay from their main job) and then divided into ten equally big groups (deciles), we see that workers in the bioeconomy clearly earn less than employees and self-employed persons working outside the bioeconomy. The differences shown in Table 21 are statistically highly significant and average payment in the wider bioeconomy is lower than in the core bioeconomy.

Table 21: Income in the bioeconomy (mean deciles) in Germany 2018

	Mean
Core bioeconomy	3.99
Wider bioeconomy	3.83
Unclear	5.57
Outside bioeconomy	5.67
Total	5.52

Differences between the two segments of the bioeconomy also appear when looking at the nationality and country of birth of workers: The agriculturally shaped core bioeconomy employs higher than average shares of persons with German nationality while persons with different backgrounds, particularly from other EU countries, work more frequently in the wider bioeconomy with its dominance of the accommodation and food sector.

Table 22: Nationality and country of birth in the bioeconomy, Germany 2018

	Core bio-economy	Wider bioecon-omy	Unclear	Outside bioecon-omy	Total
Nationality					
German	95.4	79.1	88.9	92.6	90.0
EU	3.0	9.7	5.5	3.6	4.9
North African, Middle East	0.2	2.4	0.8	0.6	0.8
Other European	0.7	4.8	3.5	2.1	3.0
Other	0.8	4.1	1.3	1.1	1.4
Country of Birth					
German	93.5	72.7	81.7	86.6	83.4
EU	3.5	10.2	7.1	5.3	6.5
North African, Middle East	0.9	4.7	3.5	2.6	3.2
Other European	1.2	6.8	5.5	3.6	4.7
Other	0.9	5.5	2.1	1.9	2.2

The breakdown of jobs by region shows in which federal states in Germany agriculture, forestry and fishing as the main sectors of the core bioeconomy are more important than elsewhere: More than twice the country-wide average share of workers in the core bioeconomy is found in Mecklenburg-Western Pomerania, a comparatively sparsely populated region in the North East characterized by extensive agriculture and – due to its coast to the Baltic Sea – fishing activities (Table 23). The likewise agriculturally shaped state of Brandenburg follows with two percent of workers employed in the core bioeconomy. Other federal states with higher shares of jobs in the core bioeconomy are: Lower Saxony, Schleswig-Holstein, Bavaria and Rhineland-Palatinate. The three city states of Berlin, Bremen and Hamburg unsurprisingly have nearly no core bioeconomy at all. These results show: The existence of a core bioeconomy based on activities in the primary sector is strongly connected to space and geographical conditions – bigger states have more opportunities for agriculture and forestry than smaller ones and only coastal states can maintain significant fishing activities (Figure 7). Employment in the wider bioeconomy is more equally distributed among the federal states, but the ones that host a stronger core bioeconomy also feature a relatively higher number of jobs in the wider bioeconomy. The front runner is again Mecklenburg-Western Pomerania where seven percent of all jobs are in the wider bioeconomy. Brandenburg and Lower Saxony hold the second highest figure with 5.6 percent.
Two reasons may be drawn on to explain why in these three states jobs in the core as well as the wider bioeconomy are more frequent than elsewhere: First, the production

chain and adjacent economic activities: There are jobs in agriculture, forestry and fishing that are related to organizing, administering and otherwise participating in the process of generating biomass – they are not part of the core but of the wider bioeconomy. If more persons work in agriculture, forestry and fishing this increases not only the core but also the wider bioeconomy. Moreover, food processing and wood manufacturing as parts of the wider bioeconomy often take place geographically close to the places of origin: slaughterhouses are near animal farms, paper mills are found in forest regions. Second, the wider bioeconomy contains accommodation and food service activities which are both highly relevant for tourism. Particularly the coasts of Mecklenburg-Western Pomerania are a very famous tourist region in Germany with millions of visitors each year. Combined with the largely rural regions towards the inland, the result is a high importance of the bioeconomy in this federal state.

Table 23: Share of bio-based jobs in regions of Germany 2018 (percent of total workforce)

	Core bio-economy	Wider bioeconomy	Unclear	Outside bioeconomy
Baden-Wuerttemberg	0.8	4.5	56.7	38.0
Bavaria	1.5	4.4	55.3	38.8
Berlin	0.1	4.4	47.6	47.9
Brandenburg	2.0	5.6	46.6	45.9
Bremen	0.0	4.7	49.4	45.9
Hamburg	0.1	3.8	50.3	45.9
Hesse	0.5	3.8	50.5	45.2
Mecklenburg-Western Pomerania	2.5	7.0	47.4	43.1
Lower Saxony	1.8	5.6	51.6	41.0
North Rhine-Westphalia	0.5	4.7	51.7	43.1
Rhineland-Palatinate	1.5	5.0	51.7	41.9
Saarland	0.5	3.7	53.6	42.2
Saxony	0.8	4.9	52.2	42.1
Saxony-Anhalt	1.2	5.5	50.2	43.0
Schleswig-Holstein	1.6	5.4	48.9	44.1
Thuringia	1.0	5.2	52.7	41.1
Total	1.0	4.7	52.4	41.9

Figure 7: Federal states in Germany, source: https://www.mygermancity.com/german-states; (accessed 21.09.2021)

Looking more generally at the spatial distribution of bioeconomic jobs in Germany, it appears that 60 percent of the persons employed in the core bioeconomy live in rural areas, one third in towns or suburbs and only six percent in cities. In contrast, from the persons working in non-bioeconomy jobs only every fifth lives in rural surroundings and about one third in densely populated cities. In Finland the urban-rural divide was even bigger (see Table 24), the reason is probably a higher density of towns and suburbs in Germany in which every third job in the core bioeconomy is located.

Table 24: Degree of urbanization and the bioeconomy, Germany 2018

Urbanisation	Core bio-economy	Wider bio-economy	Unclear	Outside bioeconomy	Total
Cities	6.0	34.4	32.9	38.7	35.1
Towns and suburbs	33.3	39.0	42.8	40.0	41.3
Rural area	60.7	26.6	24.3	21.3	23.5

4.2. Working Conditions

As in Finland the core bioeconomy in Germany is dominated by small business owners (farmers) and unskilled workers and, to a smaller extent, by family workers. However, the share of small business owners is smaller in the German core bioeconomy, although still ten times as high as in the total labour force (Table 25). Moreover, unskilled workers are more common in the German than in the Finnish core bioeconomy and clearly exceed the average percentage in the labour force. The same tendency is apparent for the professional status of core bioeconomy workers: while self-employment occurs more often than on average, the figures are smaller than in Finland. This difference can be explained only partly by the general composition of the labour market in both countries: In Finland self-employment and small businesses are much more common than in Germany while the latter country has a higher share of unskilled workers in the labour force. Nonetheless unskilled workers concentrate in unusual high proportions in both segments of the German bioeconomy. The wider bioeconomy in Germany is shaped by a strong predominance of unskilled workers who make up for almost three quarters of all persons in this sector – more than twice as on average.

Table 25: Occupational structure of the bioeconomy in Germany 2018

	Core bio-economy	Wider bioecon-omy	Unclear	Outside bioecon-omy	Total
Oesch occupational classes					
Higher-grade service class	4.6	4.2	16.4	22.1	18.1
Lower-grade service class	1.6	2.0	13.3	32.2	20.7
Small business owners	46.8	4.7	5.0	3.7	4.8
Skilled workers	8.6	16.5	25.4	20.1	22.6
Unskilled workers	38.4	72.5	40.0	21.9	33.9

Professional status					
Self-employed	44.2	8.0	10.8	7.9	9.8
Employee	42.3	90.8	89.0	92.0	89.8
Family worker	13.5	1.2	0.2	0.1	0.3

The high shares of unskilled work in the German bioeconomy may be a sign that also non-standard employment and atypical forms of work occur more often. So, are employment contracts more often limited/temporary in the bioeconomy, how many persons work part-time and which unusual working hours characterize the jobs in the core and wider bioeconomy in Germany?

The results in Table 26 indicate that, with the exception of a slightly increased proportion of persons holding a second job, the German core bioeconomy is not specifically characterized by non-standard employment. In contrast, the standard forms 'permanent contract' and 'full-time employment' occur significantly more often than in the total labour force. In Finland's bioeconomy both non-standard forms occur more often than in Germany and more often than on average.

Table 26: Non-standard employment in the bioeconomy in Germany 2018

	Core bio-economy	Wider bio-economy	Unclear	Outside bioeconomy	Total
Permanent	88.5	86.6	88.8	86.9	87.9
Temporary	11.5	13.4	11.2	13.1	12.1
Full-time	77.9	64.2	76.1	66.4	71.5
Part-time	22.1	35.8	23.9	33.6	28.5
Second job	5.9	4.8	4.7	6.0	5.3

In the wider bioeconomy temporary contracts are marginally more prevalent, but only about one percentage point higher than average. Much more common, however, is part-time employment, more than every third person is working part-time in the wider bioeconomy. Part-time jobs in Germany are particularly widespread in the hotel and gastronomy sectors which belong to the accommodation and food service activities.

As explained in the previous chapter about Finland, work in the bioeconomy is often related to atypical working hours due to the fact that animals, plants and bio-based resources often require timely treatment and processes cannot be rationalized, normed and planned so much as if dealing with non-organic materials. The results for Germany confirm this assumption: Persons in the agricultural core bioeconomy very often work at the weekends and evenings and more often in the nights than an

average person in the labour force, for example, 60 percent of the workers in the core bioeconomy sometimes or usually work on Sundays – outside the bioeconomy 23 percent of the workers report to do so (Table 27). Only shift work, the incarnation of standardized working hours, occurs very seldom in the core bioeconomy and less often than outside the bioeconomy. Compared to Finland, the shares that work in the evenings and nights are slightly lower – a fact that may be explained by the geographical location of the Northern European country where winters and periods of darkness are longer.

Table 27: Atypical working hours in the bioeconomy in Germany 2018 (cumulated shares for 'usually' and 'sometimes')

Usually or sometimes:	Core bio-economy	Wider bio-economy	Unclear	Outside bioeconomy	Total
Shift work	5.6	17.6	15.4	14.5	15.1
Evenings	52.2	43.1	33.1	34.4	34.3
Nights	17.4	16.6	9.5	11.9	10.9
Saturdays	74.0	53.8	35.0	32.2	35.0
Sundays	60.1	36.9	14.6	22.6	19.5

In both countries the structure of reported working hours for the wider bioeconomy is similar: persons here more often work at evenings, nights and weekends – not so much as in the core bioeconomy but still clearly above average. A difference is that shift work is less widespread in the German wider bioeconomy than in the Finnish which could be an indication for different work cultures in the accommodation and gastronomy sector in both countries: While in Finland working hours seem more structured and standardized in this sector, they are more flexible in Germany with more part-time and less shift work.

In summary, working conditions in the German bioeconomy in terms of occupational status, employment forms and working hours are determined by peculiarities that differ between the core and wider bioeconomy: Like in Finland, the agriculturally-shaped core bioeconomy features high fractions of self-employed persons and small business owners (farmers), however, among employees in this sector, permanent and full-time contracts are more frequent in the German than in the Finnish core bioeconomy. This may be attributed to a higher degree of informality of labour relations in the Finnish core bioeconomy and more formalized, regulated work in Germany. In both countries the wider bioeconomy heavily draws on the labour of unskilled workers – a situation which is often associated with precarious working conditions such as low incomes, insecurity and a hazardous work environment. While the first is confirmed for the German wider bioeconomy (see the comparatively lowest incomes of persons in the wider bioeconomy in Table 21), the other factors need to be explored

in more depth in future research. Finally, in both countries the two segments of the bioeconomy are characterized by atypical working hours with the one exception of shift work in the core bioeconomy that occurs less often than elsewhere in the economy.

The core bioeconomy that deals with the production of biomass is a sector where independent work, ownership of a business and/or land as well as working times adapted to natural cycles create unique work arrangements that seem to attract men more than women. In the wider bioeconomy where further processing of biomass takes place, patterns of utilizing cheap labour force (low paid, unskilled, migrants) under potentially precarious conditions are very common. As jobs in the wider bioeconomy require comparatively low qualification levels, employers can draw on large quantities of persons able and willing to work in restaurants and bars or in the assembly lines of large manufacturing plants handling wood, meat and other bio-based materials.

4.3. Comparison with the German Bioeconomy Monitoring

In this section a comparison of the composition and development of the German bioeconomy is carried out between the results yielded with the approach of the German bioeconomy monitoring (Bringezu et al. 2020) and the outcomes that are generated by applying the typology suggested here.

The employment statistics of the German bioeconomy monitoring are also based on the data of the EU-LFS. Using its estimations for the bio-based shares of different economic sectors, the report finds that 2010 the bioeconomy provided employment equal to a number of 3.1-3.7 million persons or jobs (ibid, p. 42). Until 2017 the numbers declined to a minimum of 3.0 and a maximum of 3.6 million persons representing 8-9 percent of the total workforce in Germany. During the observed time overall employment in Germany increased by about 9 percent, while employment in the bioeconomy slightly decreased by about 2 percent. This trend is mainly due to declines in agriculture and manufacturing. On the other side, the report finds some increases in food and beverage services, construction and research and development. The same trends of a general decline of employment in the bioeconomy mainly caused by automation processes in the primary sector as well as slight increases in the food and beverages sectors occurred in the EU 27 and the United Kingdom (Porc, Hark, Carus et al. 2021).

Moreover, the German bioeconomy monitoring explores the distribution of employment in the bioeconomy over sectors. The biggest share in their calculations is held by manufacturing with between 39 and 45 percent, followed by food and beverage services with 27-33 percent. Agriculture lies between 13-16 percent and construction activities make up for 8-10 percent. Research and development together with the bio-based shares of the energy sector are responsible only for about five percent of

employment in the bioeconomy. The report identifies no changes in this distribution over the observed time period from 2010 to 2017. The report predicts a further decrease of employment in the bioeconomy as shrinking numbers in agriculture, manufacturing and construction will not be compensated by only slowly rising employment in food and beverages services and research and development.

The calculations based on the typology of jobs in the bioeconomy introduced here lead to somewhat different results (see Figure 8). First of all, the share of employment in the bioeconomy is lower when measured by economic sector and occupation: In 2011, the core and the wider bioeconomy together constitute 6.3 percent of the total workforce in Germany. Second, the decline of employment in the bioeconomy comes out more pronounced as in 2019 the share has dropped to 5.6 percent. In total numbers, about 2.5 million persons were employed in the bioeconomy in 2011, in 2019 this applies to 2.3 million persons. The main reason for the lower numbers compared to the German bioeconomy monitoring and other approaches that use estimated bio-based shares of sectors, is the narrower measurement of the bioeconomy that is used here when including only the core and wider bioeconomy. The German bioeconomy monitoring includes estimations for partly bio-based sectors which in the typology here are classified as unclear cases. A ten percent lumber rate in construction, for example, doesn't mean that ten percent of all jobs in the construction sector are working exclusively with this bio-based material. Working with lumber will be more widespread among jobs in construction as most workers will sometimes handle wooden materials. Thus, it cannot be said for most jobs whether they belong to the bioeconomy or not. Using occupation in addition to economic sectors provides more details about the actual jobs that people hold and enables creating the above introduced typology. Now it can be claimed more precisely that in 2019 2.3 million persons actually had a job in the bioeconomy compared to the statement of the German bioeconomy monitoring that the combined bio-based shares of all economic sectors equaled between 3.0 and 3.6 jobs that people held in 2017.

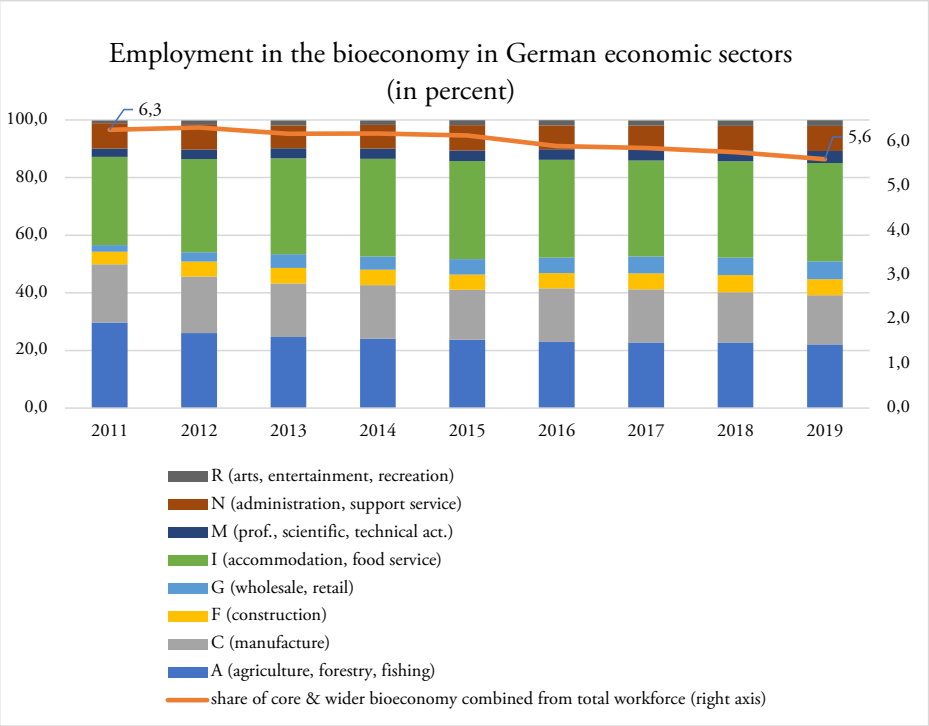

Figure 8: Composition and development of the German bioeconomy (core and wider bioeconomy combined), own calculations with EU-LFS data from 2011-19

Regarding the composition of the bioeconomy, we find a few differences between the German bioeconomy monitoring and the results of this paper: Using 2017 as year of comparison (Table 28), the biggest share in the analyses here is reported for food and beverage services which account for exactly one third of all jobs in the bioeconomy. While the monitoring reports equal numbers for this sector, it estimates a much bigger share for manufacturing (up to 45 percent) – according to the analyses carried out in this paper, manufacturing only comprises 18.4 percent of all jobs in the bioeconomy. In contrast, agriculture, forestry and fishing play a greater role in the analyses based on the typology of jobs and account for about 23 percent of the jobs in the bioeconomy compared to the max. 16 percent in the monitoring report. Also, construction as well as research and development (together with the energy sector) contribute proportionally less jobs to the bioeconomy according to the approach carried out in this paper.

Table 28: Comparing the German bioeconomy monitoring with the typology of jobs in the bioeconomy

Economic activities (Shares from the bioeconomy in 2017, in percent)	Bioeconomy monitoring (Bringezu et al. 2020)	Typology of jobs in the bioeconomy
Agriculture, forestry, fishing	13-16	22.8
Manufacturing	39-45	18.4
Food and beverage services	27-33	33.3
Construction	8-10	5.5
Research and development plus energy	5	4.1

Finally, a look at the change in the distribution of bioeconomy jobs among sectors over time reveals that, in contrast to the findings of the monitoring report, some interesting changes happened: First, employment in agriculture, forestry and fishing declined, leading to a drop in its share of the bioeconomy from 29.7 percent in 2011 to 22.1 in 2019. Also, manufacturing declined from 20.2 percent to 17.1 percent. At the same time, employment in food and beverage increased its share from 30.6 percent to 34.1 percent. Trading with bio-based goods in wholesale and retail more than doubled its share and grew from 2.3 percent to 6.2 percent. This might be an indication that during the observed period consumption driven demand for bio-based goods has increased. The share of jobs in research and development in the bioeconomy in Germany increased from 2.9 to 4.2 percent. Overall, these results point to a shift of the jobs in the bioeconomy away from more technical and manual toward rather interpersonal and cognitive work. Or in other words: The German bioeconomy is undergoing a transformation where the production and processing of biomass is more and more standardized, automated and probably also outsourced to other countries, thus requiring less and less human labour in Germany, while research with bio-based materials, development of innovative products, processes and infrastructures (biotechnology) and its economy-wide distribution are on the rise.

5. Conclusions

Discussing existing measurement and monitoring concepts of the bioeconomy, this paper has shown a gap in research about assessing employment and jobs in the bioeconomy resulting in a corresponding lack of research on the social structure and working conditions of the bioeconomy. As a contribution to filling this gap, this paper introduced a typology of jobs based on economic sectors and occupations and differentiating between the core and the wider bioeconomy as well as a category for jobs outside the bioeconomy. This new approach allows for comparing jobs and

workers in the bioeconomy and outside of it regarding all aspects that are usually covered with data from social surveys, such as the European Union Labour Force Survey.

In the paper two applications were demonstrated: First, an analysis of the Finnish and German bioeconomy dealing with the social composition of bioeconomy workers and an assessment of their employment situation and working conditions. Second, a look at the extent and sectoral distribution of the German bioeconomy over the last ten years in comparison to the approach of the German bioeconomy monitoring report (Bringezu et al. 2020). For future analyses, a benefit of the approach suggested here is that the social structure and working conditions of the bioeconomy can be investigated both at different levels (regional, national) and in comparative (cross-country) perspective.

The results of the two applications show that 1) working conditions in large parts of the bioeconomy are highly unstandardized (in the primary sector as well as in the food and beverages service sector) – this may be an indication that precarious conditions, insecurity and poverty risks are more frequent in the bioeconomy than on average in the economy. 2) At least in Germany (and similar developments occur in most early industrialized countries) jobs in the bioeconomy have declined constantly over the last years and may have reached a minimum as the potential for further decreases in the primary sector seems exhausted with already less than one percent of the labour force working in the agriculture, forestry and fishing sector. At the same time, both overall employment and job growth perspectives in bioeconomic research and development are, to date, very small.

More generally, the study has shown that work in the core bioeconomy, i.e. in agriculture, forestry and fishing where primary biomass is produced, is different from work in other segments of the bioeconomy where biomass is processed, researched and distributed. Self-employment, ownership and dependence on natural cycles are central features that are related to the production of biomass and that emerge from the fact that activities like cultivating and harvesting food plants and wood, hunting animals etc. are genuinely land-bound activities. Moreover, the handling of bio-based materials depends on geographical, climatic and temporal conditions like seasons, sunlight, temperature and so on which make it difficult to scale-up production at the push of a button. Yet particularly the agricultural sector has experienced unprecedented levels of standardization, mechanization and automation in early industrialized countries, there will always remain a rest that eludes the capitalist economic logic: The growth of plants and animals follows recurring natural cycles and while such biological processes may be technologically accelerated and optimized to some extent, there are inherent biophysical limits and uncontrollable risks such as weather phenomena to this. These limits and risks affect work in the core bioeconomy specifically but can be observed also in the different economic sectors of the wider bioeconomy. Thereby, the effects of being dependent on biophysical limits on work more and more disappears

further down the line in the production chain: Factories that process plants often run at full capacity only a few weeks per year after the plants were harvested, some regional and seasonal food is only available during certain periods of the year but retail companies offer imported food throughout the whole year, leather, textiles and paper, for example, as already processed bio-based goods, are more durable, can be stored, piled-up and traded independently from seasons and outside conditions. Such within-differences of the bioeconomy need to considered when trying to assess its characteristic working conditions and social structure. Further research should therefore engage more in sector-specific analyses of the bioeconomy and compare beyond the degree of destandardized and precarious employment and atypical working hours aspects like autonomy and variety of work tasks, health and well-being at work, work-life-balance and other dimensions of job quality.

With regard to the bioeconomy's contribution to post-fossil transformations, the results of this study seem to suggest that progressive impulses can mostly be expected in technology and resource substitution. A general change of the occupational structure or working conditions through 'a rise of the bioeconomy' is nowhere in sight. Transformations in and of the working world are stimulated by other social processes such as digitalization and demographic change which in turn will have impacts also for the jobs in the bioeconomy. In order to investigate these changes more detailed data is needed which allows a more precise measurement of economic sector and occupation. Combined with survey questions about working conditions and attitudes towards social and ecological issues a nuanced picture of the societal and mental implications of working in the bioeconomy could be created. Future research should also compare the social structure of bioeconomic jobs between different countries that follow different bioeconomy strategies and analyze the change of the occupational structure more in general, to look how overall trends in the world of work relate to the beginning transition from fossil to biological resources.

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