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D 1.3 Methodology of comparison between supply chains: environmental, social and economic indicators

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3. Introduction and background

This Deliverable 1.3 outlines a methodology aimed at comparing the environmental, social and economic sustainability of existing technologies for the treatment and valorisation of by-products and waste from primary production and the agri-food sector identified through the preliminary activities of the WP1.

In particular, in the preliminary tasks, the most significant production chains for the territorial specificity of each Partner will be analysed, with the study of the best technologies for the production of by-products and the valorisation of waste streams, through the breakdown of the value generation process.

Sustainability indicators for the evaluation of the different value chains will be derived from conventional assessment methodologies, namely: Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Mass Flow Analysis (MFA).

The Life Cycle Assessment (LCA) methodology has been identified as the most suitable tool for assessing of the sustainability of agricultural and agri-food production value chains, including the valorisation of waste and by-product flows. LCA (SETAC, 1999) is a systematic methodology for the quantification and evaluation of the environmental loads associated with a product, through the identification of material and energy flows throughout its life cycle, from the production / extraction of raw materials to disposal of the product itself once it reaches the end of its life (from cradle to grave approach).

Life Costing Analysis (LCC) is a useful tool for companies to understand the costs of each step of the Life Cycle of a product or service, from its pre-production to its final disposal.

The Material Flow Analysis (MFA) methodology consists of a systematic evaluation of material flows and stocks within a system (Brunner and Rechberger, 2004). This method allows the division of material flows along the supply chain to be quantified and it is important that it is combined with systems for quantifying the cost and value of the same flows.

According to the basic metrics used in the methodologies described above, the different selected technologies will be compared on the basis of their sustainability in economic, environmental and social terms.

4. Methodology

The technologies selected by different project partners at the level of specific individual supply chain identified for the valorisation of by-products at territorial level will be characterized by environmental, social and economic impact indicators that will allow us to compare the sustainability of the different technologies applicable to the respective value chains for different by-products.

The sustainability of the agricultural and agri-food supply chain, especially regarding the processes of valorisation of waste flows and by-products, must address not only the management and economic aspects, but also the environmental and social ones.

For the environmental sustainability aspect, it is necessary to minimize environmental services for the needs of the supply chain: that is, to minimize energy, water and soil consumption (impact on the source), to give adequate fate to secondary flows by minimizing the residual fraction not recoverable as a secondary raw material and emissions of climate-altering gases.

From the point of view of social sustainability, reference is made to the importance of the bioeconomy sector and the increase in jobs determined by the implementation of new valorisation chains.

For the aspect of economic sustainability, in addition to maximizing the entrepreneur's profit, the focus is on economic growth, an open and competitive economy, investments in human capital and social capital and distributional equity.

The summary table of the comparison indices (see below) shows the main indicators that can be used to evaluate the sustainability of the analyzed supply chains.

For the environmental aspect, the indicators chosen are:

- the carbon footprint, which expresses in kg CO_2 equivalent, the total greenhouse gases (GHGs) emitted during production, transformation and distribution (since GHGs have different effects on global warming they are converted into CO_2 equivalents based on what was established by the Intergovernmental Panel on Climate Change – IPCC, 2007) of a kg of final product;
- the water footprint, which expresses the quantity of water used for the final product (m^3 per kg of final product, see for example https://www.waterfootprint.org/);
- energy use, expressed in kWh per kg of final product;

- the ecological footprint, which expresses the bioactive surface necessary to produce consumer objects and absorb the necessary CO_2 produced (hectares of bioactive surface per kg of final product).
- the food miles indicator, which expresses the kilometers travelled by a product from production to consumption (km per kg of final product).

Considering the social aspect, indicators essentially concern employment:

- increase in territorial system employment, which is measured through the ratio between the number of employees in the bioeconomy sector and that of the territorial economy as a whole; it is the % share represented by the bioeconomic sector in terms of number of employees and turnover on the same values as the local economy as a whole;
- improvement of Social Capital, which is measured through the improvement of the qualification of employees along the value chain of bioeconomic supply chains compared to traditional ones.

As regards the economic aspects, the indicators that can be used refer to:

- contribution to circularity: kg of by-product per kg of final product used (quantifiable through the cost value: missed raw material purchase costs; missed waste management costs; production costs of the valorised product, secondary raw material compared to the traditional product);
- CEI (Circular Economic Index): value of the material produced over the value of the source material (calculation of the Added Value along the value chain).

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In detail, the sustainability indicators identified for the assessments are the following:

SUSTAINABILITY OF THE SUPPLY CHAIN		
ENVIRONMENT	**SOCIETY**	**ECONOMY**
- ***Water footprint:*** volume of H_2O consumed/kg of final product - ***Food miles:*** km supply distance/kg final product - ***Cumulative Energy demand:*** KWh/kg of final product - ***Carbon footprint:*** kg CO2 eq/kg of final product - ***Ecological footprint:*** Km2 used/ kg final product	- **number of employees of bioeconomysector/total number of employees working on territory** - **% share represented by the bioeconomysector:** n. employees and turnover/ no. employees and turnover general territorial economy - **High profile employees (scientific degrees)/medium profile employees along the value chain**	- **kg by-product/kg final product**(evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) - **CEI index: value of the material produced/value of the original material** (calculation of the Added Value)

The value chain analysis through the use of indexes represents a tool for analyzing and breaking down the value generation process. These information are fundamental to define the most interesting value chains for a given Region according to the following points:

- to quantify the division of the value of the goods produced along the supply chain;
- to identify the economic subjects involved in the production process (and also the exchange price of the good between the subjects involved);
- to identify the contribution of the different processes and products in the supply chain for the calculation of the Added Value (AV);

to calculate the AV contributed by each sector that enters the production cycle (reconstruction of the value chains for the analyzed supply chains).

For each phase of the product life cycle, alongside the data on the resources used and the technologies used, the economic data will be taken into consideration to evaluate the cost-effectiveness of the process.
For each supply chain and for the specific technology it will be possible to define the related market scenarios.
The choice of the best solution can be identified through the definition of market scenarios where, through environmental and socio-economic assessments and flows of used resources, possible implications and critical issues of the system can be identified.
The economic component, alongside the physical one of mass flows, with the related indicators, allows us to obtain an overall picture in terms of optimization of the circular economic system and overall sustainability of a given value chain.

5. Sustainability indicators for the Italian Value Chains (PP1)

5.1 Sustainability indicators for Value Chain - GRAPES/WINE

Table 1. Indicators evidenced for grapes/wine value chain - ITALY-PP1

ENVIRONMENT	SOCIETY	ECONOMY
Water footprint: volume of H_2O consumed/kg of final product 850 L water per L of wine (including irrigation) 2-4 L water per L of wine (only cellar production)	**n. of employees of bioeconomical sector/total number of employees working on territory** 100.000/2.200.000 (considering agriculture, food and beverage) (to be revised / confirmed)	**kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product 0.25 kg by product (lees and vinasses) per kg of grape treated or 0.35 kg by product (lees and vinasses) per liter of wine
Food miles: km supply distance/kg final product 0,018 km/liter of wine (considering 12000 kg of grapes per single transport, 15 km average distance from vineyard to cellar)	**% share represented by the bioeconomic sector:** n. employees and turnover/ no. employees and turnover general territorial economy Employes 4.5 % (bioeconomy on total) Turnover 3% (bioeconomy: 4.769 million € Total 165.786 million €)	**CEI index: value of the material produced/value of the original material** (calculation of the Added Value) Ethanol: 0.028 €/kg vinasses Tartaric Ac: 0.585 €/kg vinasses Polyphenols: 1.75 €/kg vinasses Vinasses 12 €/100 kg (0.12 €/kg)

	(to be revised / confirmed)	CEI Ethanol: 0.25 Tartaric Acid: 4.87 Polyphenols: 14.58
Cumulative Energy demand: KWh/kg of final product 0.82 kWh/liter of wine	**High profile employees (scientific degrees)/medium profile employees along the value chain** Share of graduates in total food industry workers: about 18%. Share of graduates in total industry: about 15%.	
Carbon footprint: kg CO_2 equiv/kg of final product 1.1 -1.4 kgCO_2/liter of wine (85% coming from winemaking and bottling) *		
Ecological footprint: m^2 used/ kg final product 1.5 m^2 / liter of wine * * calculated		

(*) Luís Pinto da Silva, Joaquim C.G. Esteves da Silva,Evaluation of the carbon footprint of the life cycle of wine production: A review, Cleaner and Circular Bioeconomy, Volume 2, 2022, 100021

5.2 Sustainability indicators for Value Chain – MILK/DAIRY

Table 2. Indicators evidenced for milk/diary value chain - ITALY

SUSTAINABILITY OF THE SUPPLY CHAIN		
ENVIRONMENT	SOCIETY	ECONOMY
Water footprint: volume of H_2O consumed/kg of final product 5-10 l water used/l milk 0,075kg cheese/kg milk used 0.6 l H_2O recovered/l whey used (membranes option) TOTAL WATER FOOTPRINT: 5-10 L/L MILK X 0.57 = 2.15-4.3 L WATER/L MILK TREATED OR 28-57 l H_2O/kg CHEESE PRODUCED	**n. of employees of bioeconomical sector/total number of employees working on territory** **UE** 1,76% of total number of agroindustry workforce **Italy** 2,1% of total number of agroindustry workforce **Veneto Region** 2,8% of total number of agroindustry workforce **Veneto Region n. of employees in bioeconomical sector of Milk/dairy produce**: 2,8% out of 6% of workers in the milk/dairy sector in Italy (n. of employees in Milk/dairy produce in Veneto Region is 6% of national employees in the milk/dairy sector)	**kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product 0.95 l by product (whey)/l milk treated 0,80 l scald/l milk treated 12 g proteins/ l whey used 4,5 g sugars recovered/l whey used
Food miles: km supply distance/kg final product 0,047 km/kg cheese (considering 10 m3 volume for single transport, 35 km average distance from milk producer to cheese producer)	**% share represented by the bioeconomic sector:** n. employees and turnover/ no. employees and turnover general territorial economy **UE** 1,76% of total number of agroindustry workforce **Italy** 2,1% of total number of agroindustry workforce	**CEI index: value of the material produced/value of the original material** (calculation of the Added Value) 3.0-4.85 euro/kg (proteins average price) 12,75 euro/1000 kg whey (2024) CEI = 2,8-4,6

	Veneto Region 2,8% of total number of agroindustry workforce	
Cumulative Energy demand: KWh/kg of final product 3.3 kWh/kg cheese (EE) 7.1 kWh/kg cheese (Heat)	**Energy recovery:** Biogas production (8.5 workers per MW installed)	
Carbon footprint: kg CO_2 eq/kg of final product 1.6 $kgCO_2$/kg cheese (EE) 1.2 $kgCO_2$/kg cheese (heat)	**High profile employees (scientific degrees)/medium profile employees along the value chain** Share of graduates in total food industry workers: about 18%. Share of graduates in total industry: about 15%.	
Ecological footprint: m^2 used/ kg final product d 0.39-0.79		

6. Sustainability indicators for Italian Value Chains Fraunhofer Italia Research (PP3)

6.1 Sustainability indicators for Value Chain - GRAPES/WINE

Table 3. Indicators evidenced for grapes/wine value chain – ITALY-PP3

ENVIRONMENT	SOCIETY	ECONOMY
Water footprint: volume of H2O consumed/kg of final product 580 Lwater/bottle of wine (V=0.75L) →773 Lwater/L wine (where the 95% of the total impact is for the upstream module) [1]	**n. of employees of bioeconomical sector/total number of employees working on territory** missing	**kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product 1.25 kg grape/Lwine 0.3 kg grape pomace/kg grape (assumption)
Food miles: km supply distance/kg final product 0.0021 km/liter of wine 1.25 kg grape/L wine (considering 18 000 kg of grapes per single transport, 30 km average distance from vineyard to cellar) [3]	**% share represented by the bioeconomic sector:** n. employees and turnover/ no. employees and turnover general territorial economy missing	**CEI index: value of the material produced/value of the original material** calculation of the Added Value) **By product**: Grape pomace (GP) 150 €/ton (0.15 €/kg) (assumption to be confirmed) **End products [2]** Costs: • Polyphenols: 20 €/kg • Grape seed oil 4 €/kg • Biochar 2.5 €/kg

		Yield: • 40.6 kg Polyph/ton GP • 49.7 kg grape seed oil/ton GP • 161.7 kg Biochar/ton GP **CEI** Polyphenols: 5.4 Grape seed oil: 1.3 Biochar: 2.7
Cumulative Energy demand: Kwh/kg of final product 0.24 kWh/liter of wine [1]	**High profile employees (scientific degrees)/medium profile employees along the value chain** Share of graduates in total food industry workers: about 18%. Share of graduates in total industry: about 15%. (to be confirmed)	
Carbon footprint: kg CO_2 equiv/kg of final product 1.07 $kgCO_2eq$/bottle of wine (V=0.75L) → 1.43 $kgCO_2eq/L$ [1]		
Ecological footprint: m^2 used/ kg final product 12.5 ton grape/ha in South Tyrol [4] 1.25 kg grape/Lwine 1 m^2 / liter of wine * * calculated		

6.2 Sustainability indicators for Value Chain - APPLE

Table 4. Indicators evidenced for apple value chain – ITALY-PP3

SUSTAINABILITY OF THE SUPPLY CHAIN		
ENVIRONMENT	**SOCIETY**	**ECONOMY**
Water footprint: volume of H_2O consumed/kg of final product 700 L water/kg apple [8] (including irrigation)	**n. of employees of bioeconomical sector/total number of employees working on territory** **South tyrol** 13 % of total number of agroindustry workforce (37 895 people in agriculture sector in the region; 269 512 tot employees in the region) >94% of cultivated soil are apple trees (ISTAT 2023) (to be revised according bioeconomical sector)	**kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product 0.195 g pectin/kg apple pomace (fresh) [6] 164 g pectin/kg apple pomace (dried) [9]
Food miles: km supply distance/kg final product 0.034 km/kg apple (considering 25 ton for single transport, 850 km average distance by truck in the Italian and European markets) [5]	**% share represented by the bioeconomic sector:** n. employees and turnover/ no. employees and turnover general territorial economy UE 1,76% of total number of agroindustry workforce **Italy** 2,1% of total number of agroindustry workforce **South Tyrol** 14% of total number of agroindustry workforce	Pectin: 10 €/kg [6] Apple pomace 0.0015 €/kg [10] CEI Pectin: 130

Cumulative Energy demand: Kwh/kg of final product 3,79 kWh/kg apple (Trentino-Alto Adige) (ASSOMELA 2022)	**Energy recovery:** (to be done)	
Carbon footprint: kg CO_2 equiv/kg of final product 0.20 kgCO_2/kg apple (commercialized in a plastic bag) [5]	**High profile employees (scientific degrees)/medium profile employees along the value chain** Share of graduates in total food industry workers: about 18%. Share of graduates in total industry: about 15%. (to be confirmed for South Tyrol)	
Ecological footprint: m^2 used/ kg final product Apple fields: 18 000 ha (South Tyrol) Tot apple production: 1 200 000 ton/year [7] 0.15 m^2/kg apple		

References

[1] Emanuele Bonamente, Flavio Scrucca, Sara Rinaldi, Maria Cleofe Merico, Francesco Asdrubali, Lucrezia Lamastra. 2016. «Environmental impact of an Italian wine bottle: Carbon and water footprint assessment.» Science of the Total Environment 560–561: 274–283.

[2] Qing Jina, Sean F. O'Keefea, Amanda C. Stewarta, Andrew P. Neilsonb,Young-Teck Kimc, Haibo Huanga. 2021. «Techno-economic analysis of a grape pomacebiorefinery: Production of seed oil, polyphenols,and biochar.» Food and Bioproducts Processing 127: 139–151.

[3] Assumption based on:

a. documentation for grape transportation in Italy https://consulenzaagricola.it/circolari/vitivinicolo/2587-circ-n-291-2014-il-trasporto-delle-uve-da-vino --> max 40 km from field to cellar (consided 30 km)
b. maximum permitted load 18 tons for single-axle vehicles (common for grape harvesting)

[4]average for different cultivar from «DISCIPLINARE DI PRODUZIONE DEI VINI A DENOMINAZIONE DI ORIGINE.» https://www.handelskammer.bz.it/sites/default/files/uploaded_files/Agricoltura/20389_disciplinare_di_produzione_DOC_Alto%20Adige_-_DM_18.09.2014.pdf

[5] Filippo Sessa, Massimo Marino, Giulia Montanaro, Alessandro Dal Piaz, Damiano Zanotelli, Fabrizio Mazzetto, Massimo Tagliavini. 2014. «Life Cycle Assessment of apples at a country level: the case study of Italy.» 9th International Conference on Life Cycle Assessment in the Agri-Food Sector. 1244.

[6] Kaushal, PC Sharma Anil Gupta and P. 2014. «Optimization of method for extraction of pection from apple pomace.» Indian journal of Natural Products and Resources 184-189.

[7] https://www.terlan.info/it/terlano/vini-e-sapori/mele/alto-adige-la-terra-delle-mele.html

[8] https://www.vip.coop/en/recipes-whispers/val-venosta-s-irrigation-system/24-3241.html n.d.

[9] Safoura Vaez, Keikhosro Karimi, Joeri F.M. Denayer, Rajeev Kumar. Evaluation of apple pomace biochemical transformation to biofuels and pectin through a sustainable biorefinery. Biomass and Bioenergy 2023, 172, 106757

[10] Gurpreet Singh Dhillon, Surinder Kaur, Satinder Kaur Brar. Perspective of apple processing wastes as low-cost substrates for bioproduction of high value products: A review Renewable and Sustainable Energy Reviews 27(2013)789–805.

7. Sustainability indicators for Slovenija Value Chains (PP2)

7.1 Sustainability indicators for VC Grape pomace/ pectin and natural colors

Table 5. Indicators evidenced for grapes pomace value chain – SLOVENIJA – PP2

SUSTAINABILITY OF THE SUPPLY CHAIN - WINE/ GRAPE POMACE (PECTIN AND NATURAL COLOURANTS)		
ENVIRONMENT	**SOCIETY**	**ECONOMY**
Water footprint: **580 l per bottle** **580 ± 30 l/bottle** The functional unit is the common 0.75 l bottle [1]	**n. of employees of bioeconomical sector/total number of employees working on territory** N (C11-beverages industry, Slovenia, 2022): 1.696 N (C10, food industry, Slovenia 2022): 18.057 N (total emploies, Slovenia 2022): 989036 [4] **1.696/989036** **18.057/ 989036**	**kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) **30 kg grape pomace/100 kg of grape / 70 L of wine** **0.7 L wine/1 kg grape** **0.3 kg grape pomace/1 kg grape** **1.43 kg grape/ L of wine**
km supply distance/kg final product **0.0046 - 0.0086 km/L of wine** distance up to max 30 km; 5-10 000 kg of grape 1.43 kg/L of wine	**% share represented by the bioeconomic sector:** n. employees and turnover/ no. employees and turnover general territorial economy No data available	**CEI index: value of the material produced/value of the original material** (calculation of the Added Value) **by-product:** **Grape pomace: 200** **Red grape pomace :300 €/t** (estimation) New product: **Grape pectin: 50-70 €/kg** (estimation) **Natural colors: 50-150 €/kg** (estim.)
Cumulative Energy demand: **0.237 kwh/l** [1]	**High profile employees (scientific degrees)/medium profile employees along the value chain**	

	No data available	**Yield of new product:** Pectin = 10 % (estimated average)[5] 10 kg pectin/100 kg grape pomace Natural color = 0.1 % (average)[6] 0.1kg natural color/ 100 kg red grape pomace **CEI (grape petcin) = 2.9 - 6 %** **CEI (grape natural colour) = 20-60 %**
Carbon footprint: **1.07 ± 0.5 kg CO_2e/bottle** [1, 2]		
Ecological footprint: Km^2 used/ kg final product **13.98 gm^2 (per bottle of wine)** [3]		

Source of data:

[1] http://dx.doi.org/10.1016/j.scitotenv.2016.04.026

[2] https://doi.org/10.1016/j.clcb.2022.100021

[3] https://doi.org/10.1016/j.agee.2008.05.015

[4] Republic of Slovenia Statistical Office

[5] https://doi.org/10.1016/j.ijbiomac.2022.10.162

[6] https://doi.org/10.1016/j.biortech.2020.123771

7.2 Sustainability indicators for VC Wood bark/ tannins

Table 6. Indicators evidenced for VC wood bark value chain – SLOVENIJA – PP2

SUSTAINABILITY OF THE SUPPLY CHAIN - WOOD/ BARK (EXTRACTION OF TANNINS)		
ENVIRONMENT	SOCIETY	ECONOMY
***Water footprint:*:** **The WF of wood for energy consumed (WF_{wec}) in the EU is 156 × 10^9 m^3/y (99% green; 1% blue) [4]**	**n. of employees of bioeconomical sector/total number of employees working on territory** **N (C16, wood industry, Slovenia 2022): 9935** **N (total empl, Slovenia 2022): 989036 [3]** **9935/989036**	**kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) **2 m^3 wood bark/ 10 m^3 wood (logs)** **(bark = 20 % of logs)** [5]
Food miles: km supply distance/kg final product **0.12 km/m^3 of sown wood**		

distance up to 50 km; up to 30 m^3 of wood 5 m^3 sowing wood form 10 m^3 wood [5]	**% share represented by the bioeconomic sector:** n. employees and turnover/ no. employees and turnover general territorial economy **No data available**	**CEI index: value of the material produced/value of the original material** (calculation of the Added Value) **by-product:** wood bark and wood of low quality **:** **price: 70 €/t = 0.070€/kg** New product: **Tannin extract: 65 €/kg** (estimation, for wine aplication) **Yield of new product:** Tanin = 6 % (estimated average)[6] 6 kg of tannins /100 kg of bark **CEI (tanin) = 1.8 %**
Cumulative Energy demand: **3.98 kwh** **(based on tannin extraction from 1 kg dried bark)** **173.05 kWh** **(based on the production of 1 kg of tannins)** [1]	**High profile employees (scientific degrees)/medium profile employees along the value chain** **No data available**	
Carbon footprint: **1 m^3 of sawn softwood (RH: 70%)** Energy: 15.8 kg CO_2e Wood: 14.8 kg CO_2e Infrastructure: 3.06 kg CO_2e Transport, vehicle over 16 tonnes: 6.08 kg CO_2e **TOTAL: 39.8 kg CO_2e** **1.64 m^3 of Slovenian sawn softwood (RH: 70%)** Fuel consumption (diesel) for machinery: 4.9 kg CO_2e Chainsaw: 6.4 kg CO_2e Site preparation: 3.5 kg CO_2e TOTAL: 14.8 kg CO_2e [2]		
Ecological footprint: ***Missing***		

[1] 10.1016/j.jclepro.2021.126807

[2] Ogljični odtis žaganega lesa iglavcev in listavcev iz slovenskih gozdov

[3] Republic of Slovenia Statistical Office

[4] https://doi.org/10.3390/w11020206

[5] CRP-V4-1824-Bridge2Bio-Zakljucno-porocilo-stisnjeno.pdf (gov.si)

[6] https://doi.org/10.1016/j.indcrop.2018.10.034

8. Sustainability indicators for Germany Value Chains (PP4)

8.1 Sustainability of the Supply Chain Beer Draff

Table 7. Indicators evidenced for beer draff value chain – GERMANY – PP4

SUSTAINABILITY OF THE SUPPLY CHAINS BEER DRAFF		
ENVIRONMENT	**SOCIETY**	**ECONOMY**
Water footprint: volume of H_2O consumed/kg of final product Beer: 3.13 L/kg [1] ***Food miles:*** km supply distance/kg final product Beer draff: 0.02 km/kg [9] ***Cumulative Energy demand:*** KWh/kg of final product Beer: 0.25 kWh/kg [1] ***Carbon footprint:*** kg CO_2 equiv/kg of final product Beer: 69.63 kg CO_2e/kg [1] ***Ecological footprint:*** Km^2 used/ kg final product Per year 0.75 qm/kg [2] 0.00000075 km^2 / kg	**n. of employees of bioeconomical sector/total number of employees working on territory** 10000 employees in breweries in Bavaria [3] 7 790 000 employees in Bavaria [4] 6 380 000 employees in Baden-Wuerttemberg [4] 1500 employees in breweries in Baden-Wuerttemberg [6] **% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy** Breweries turnover in Bavaria: 2116,4 Mio € [7] Breweries turnover in Baden-Wuerttemberg: 521,5 Mio € [7]	**kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) Biochar: 1 kg beer draff (wet)/0.133 kg biochar [8] Biopackaging: 1 kg beer draff (wet)/0.250 kg packaging [estimate based ob dry mass, addition of additives (10%) and loss during process (10%)] **CEI index: value of the material produced/value of the original material**

	BIP Bavaria: 768469 Mio € [5] BIP Baden-Wuerttemberg: 615017 Mio € [5] Share employees: 0.08 % Share turnover: 0.19 % **High profile employees (scientific degrees)/medium profile employees along the value chain** No data available	(calculation of the Added Value) Biochar: 1600/56 = 28.6 Biopackaging: 2500/56 = 44.6 Based on wet draff and estimated value according to D.1.4

[1] Beverage Industry Environmental Roundtable. (2024). 2023 BIER Benchmarking Executive Summary Report. Available online at https://www.bieroundtable.com/wp-content/uploads/2023-BIER-BenchmarkingExecutive-Summary-Report.pdf.

[2] Tuomas Mattila; Tuomas Helin; Riina Antikainen (2012). *Land use indicators in life cycle assessment. , 17(3), 277–286.* doi:10.1007/s11367-011-0353-z

[3] Getränke - München - Brauerei-Mitarbeiter fordern zwölf Prozent mehr Lohn - Bayern - SZ.de (sueddeutsche.de)

[4] Industriebericht Bayern 2023

[5] BIP | Statistikportal.de

[6a] NGG.Südwest: Tarifabschluss Brauer Baden-Württemberg

[6b] untitled (landtag-bw.de)

[7a] Umsatz der Brauwirtschaft in Deutschland bis 2022 | Statista

[7b] statistischer-bericht-brauwirtschaft-2140922237005.xlsx (live.com)

[8] Vorhabensbeschreibung (energetische-biomassenutzung.de)

[9] estimate based on 25 t transport by 500 km

7.2 Sustainability of the Supply Chain based on hemp

Table 8. Indicators evidenced for hemp value chain – GERMANY – PP4

SUSTAINABILITY OF THE SUPPLY CHAINS BASED ON HEMP		
ENVIRONMENT	**SOCIETY**	**ECONOMY**
Water footprint: volume of H_2O consumed/kg of final product Fibres: 2 719 L/kg [1] Shives: 3 987 L/kg Shives by mass balance of fibre value ***Food miles:*** km supply distance/kg final product 4 x 10^{-3} km/kg [10] ***Cumulative Energy demand:*** Kwh/kg of final product Hemp: 4.95 kWh/kg [2] Fibres: 1.49 kWh/kg Shives: 2.77 kWh/kg Fibres and shives by mass balance of hemp value ***Carbon footprint:*** kg CO_2 equiv/kg of final product Hemp: 0.975 kg CO_2e/kg [2] Fibres:0.293 kg CO_2e/kg Shives:0.546 kg CO_2e/kg Fibres and shives by mass balancing of hemp value ***Ecological footprint:*** Km^2 used/ kg final product Per year, mass balance for cultivation:	**n. of employees of bioeconomical sector/total number of employees working on territory** Employees in agriculture: BW 67 000 [4] BY 113 900 [4] No data available, the share of hemp industry of total industry is estimated to be significantly lower compared to rapeseed. 7 790 000 employees in Bavaria [11] 6 380 000 employees in Baden-Wuerttemberg [11] **% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy** BIP Bavaria: 768 469 Mio € [5] BIP Baden-Wuerttemberg: 615 017 Mio € [5] In agricultural sector: BY 5300 Mio € [6] BW 1600 Mio € [7] Values for agriculture: Share employees: 1.28 %	**kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) Hempshives: hempbioocomposites 75% hempshives for concrete = ¾=0.75 [8] Hempfibres: hemp-textiles: 0.8 90% of hempfibres (cellulose + semicellulose) are usedful for textile, 10% lost in processing [9] **CEI index: value of the material produced/value of the original material** (calculation of the Added Value) Textile: 30 €/running metre / 200 €/ton Hemp composite: 21.2

Fibres: 1.3 x 10^{-5} km^2/kg [3] Shives: 2.4 x 10^{-5} km^2/kg	Share of turnover: 0.50 % **High profile employees (scientific degrees)/medium profile employees along the value chain** No data available	

[1] Averink, J. 0198501 openbaar.pdf (utwente.nl)
[2] Energy and carbon footprint assessment of production of hemp hurds for application in buildings - ScienceDirect
Flavio Scrucca, Carlo Ingrao, Chadi Maalouf, Tala Moussa, Guillaume Polidori, Antonio Messineo, Claudia Arcidiacono, Francesco Asdrubali,
Energy and carbon footprint assessment of production of hemp hurds for application in buildings, Environmental Impact Assessment Review, Volume 84, 2020.
[3] Ecological Footprint and Water Analysis of Cotton, Hemp and Polyester (sei.org)
[4] Arbeitskreis "Erwerbstätigenrechnung des Bundes und der Länder". Berechnungsstand: Februar 2024
[5] BIP | Statistikportal.de
[6] Landwirtschaftsausschuss: Vorstellung des Agrarberichts 2022 | Bayerischer Landtag
[7] Regionale Landwirtschaftliche Gesamtrechnung (R-LGR), Berechnungsstand: September 2023. PWS | Statistikportal.de
[8] Allin, Steve.: *Building with hemp*. Seed Press, Kenmare, Co. Kerry 2005, ISBN 0-9551109-0-4.
[9] Zimniewska M. Hemp Fibre Properties and Processing Target Textile: A Review. Materials (Basel). 2022 Mar 3;15(5):1901. Hemp Fibre Properties and Processing Target Textile: A Review - PMC (nih.gov)
[10] estimate based on transport of 25 t for 100 km
[11]Industriebericht Bayern 2023

7.3 Sustainability of the Supply Chains based on rapeseed

Table 9. Indicators evidenced for rapeseed value chain – GERMANY – PP4

SUSTAINABILITY OF THE SUPPLY CHAIN BASED ON RAPESEED		
ENVIRONMENT	**SOCIETY**	**ECONOMY**
Water footprint: volume of H_2O consumed/kg of final product Rapeseed (rain-fed): Green: 1783 L/kg Blue: 0 L/kg Grey: 356 L/kg Rapeseed cake: Green: 837 L/kg Blue: 114 L/kg Grey: 165 L/kg [1] ***Food miles:*** km supply distance/kg final product 8 x 10^{-4} km/kg [11] ***Cumulative Energy demand:*** Kwh/kg of final product Rapeseed: 7.4 kWh/kg [2] ***Carbon footprint:*** kg CO_2 equiv/kg of final product Rapeseed, dried: 1.19 kg CO_2e/kg Rapeseedcake: 0.72 kg CO_2e/kg [3] ***Ecological footprint:*** Km_2 used/ kg final product Per year	**n. of employees of bioeconomical sector/total number of employees working on territory** Employees in agriculture: BW 67 000 [6] BY 113 900 [6] Proportion: 0.013 share of rapeseed oil of total oil produced in Germany:84 % [7] **% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy** BY 5300 Mio € [8] BW 1600 Mio € [9] BIP Bavaria: 768 469 Mio € [10] BIP Baden-Wuerttemberg: 615 017 Mio € [10] Values for agriculture: Share employees: 1.28 % Share of turnover: 0.50 % **High profile employees (scientific degrees)/medium profile employees along the value chain** No data available	**kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) In case of direct use (without extraction steps): 1 **CEI index: value of the material produced/value of the original material** (calculation of the Added Value) In case of direct use (without extraction steps): 1

Rapeseed oil: 0.000002 km^2/kg [4] Not available for rapeseed and cake Yield oil out of rapeseed: 40 % Estimate for rapeseed cake: 0.000003 km^2/kg [5]		

[1] hess-15-1577-2011.pdf (copernicus.org)

[2] Energy Analysis for Biodiesel Production from Rapeseed Oil (sagepub.com)

[3] Sustainability | Free Full-Text | Environmental Impacts of Rapeseed and Turnip Rapeseed Grown in Norway, Rape Oil and Press Cake (mdpi.com)

[4] Ökologische Fußabdrücke von Lebensmitteln und Gerichten in Deutschland (ifeu.de)

[5] Multitalent RAPS - RAPOOL

[6] Arbeitskreis "Erwerbstätigenrechnung des Bundes und der Länder". Berechnungsstand: Februar 2024

[7] 2021BerichtOele.pdf (ble.de)

[8] Landwirtschaftsausschuss: Vorstellung des Agrarberichts 2022 | Bayerischer Landtag

[9] Regionale Landwirtschaftliche Gesamtrechnung (R-LGR), Berechnungsstand: September 2023. PWS | Statistikportal.de

[10] BIP | Statistikportal.de

[11] estimate based on 25 t transport by 20 km

7.4 Sustainability of the Supply Chain based on wood

Table 10. Indicators evidenced for wood value chain – GERMANY – PP4

SUSTAINABILITY OF THE SUPPLY CHAIN BASED ON WOOD		
ENVIRONMENT	**SOCIETY**	**ECONOMY**
Water footprint: volume of H_2O consumed/kg of final product wood: 366 L/kg [1] ***Food miles:*** km supply distance/kg final product wood: 0.004 km/kg [2] ***Cumulative Energy demand:*** Kwh/kg of final product 0 KWh/kg for wood waste [3] ***Carbon footprint:*** kg CO_2 eq/kg of final product 0.64 kg CO_2e/kg [4] ***Ecological footprint:*** Km2 used/ kg final product Wood: 1.5 x 10^{-6} km^2/kg [5]	**n. of employees of bioeconomical sector/total number of employees working on territory** In wood and forestry: BY: 163900 [6] BW: 175.000 [7] Total: 7 790 000 employees in Bavaria [8] 6 380 000 employees in Baden-Wuerttemberg [8] Share: 0.024 **% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy** 31 Mrd Baden-Wuerttemberg [7] 44 Mrd Bayern [6] BIP Bavaria: 768 469 Mio € [9] BIP Baden-Wuerttemberg: 615 017 Mio € [9] Share employees: 2.4 % Share turnover: 5.4 %	**kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) No data available **CEI index: value of the material produced/value of the original material** (calculation of the Added Value) > 4 [10]

	High profile employees (scientific degrees)/medium profile employees along the value chain No data available	

[1] Ignacio CAZCARRO, Joep F. SCHYNS, Iñaki ARTO, M. Jose SANZ, Nations' water footprints and virtual water trade of wood products, Advances in Water Resources, Volume 164, 2022. Nations' water footprints and virtual water trade of wood products - ScienceDirect

Schyns JF, Vanham D. The Water Footprint of Wood for Energy Consumed in the European Union. *Water*. 2019; 11(2):206. https://doi.org/10.3390/w11020206

PowerPoint Presentation (unece.org)

[2] based on the estimate of a 25 t transport of 100 km

[3] Wood waste is a byproduct of high value products (e.g. furniture, constrcuction materials) and as of now is not used in high value applications, therefore the energy consumption can be distributed 100 % to the main product.

[4] CO_2 Speichersaldo (co2-speichersaldo.de)

PowerPoint Presentation (unece.org)

[5] Bayerische Staatsforsten | Was leisten eigentlich unsere Wälder (baysf.de)

[6] Beschäftigte und Umsätze (bayern.de)

[7] Forst und Holz: Clusterportal BW (clusterportal-bw.de)

[8] Industriebericht Bayern 2023

[9] BIP | Statistikportal.de

[10] D.1.1.1

8. Sustainability indicators for Polish Value Chains (PP5 and PP6)

8.1 Sustainability indicators for Value Chain - wasted fruit and vegetable / Biogas and fertilizer

Table 11. Indicators evidenced for wasted fruit and vegetables value chain – POLAND – PP5 PP6

ENVIRONMENT	SOCIETY	ECONOMY
Water footprint: volume of H_2O consumed/kg of final product 500 – 1000 L/kg (doi: 10.1016/j.jclepro.2015.03.084)	**n. of employees of bioeconomical sector/total number of employees working on territory** 175.3 k / 867.8 k (https://datam.jrc.ec.europa.eu/datam/mashup/BIO_REG_EU/)	**kg by-product/kg final product** 46% biogas 46% fertilizer
Food miles: km supply distance/kg final product 0.014 km/m^3 (considering 12 000 kg of biomass per single transport, 50 km distance from supplier to production site; Biogas yield is estimated 300 m^3/t biomass)	**% share represented by the bioeconomic sector: n.** 20.2% (https://datam.jrc.ec.europa.eu/datam/mashup/BIO_REG_EU/)	**CEI index: value of the material produced/value of the original material** 11% biogas 1,8% fertilizer
Cumulative Energy demand: KWh/kg of final product 2.8 kWh/m^3 (https://doi.org/10.1016/j.scitotenv.2019.03.211)	**High profile employees (scientific degrees)/medium profile employees along the value chain** 0.2-0.3	
Carbon footprint: kg CO_2 equiv/kg of final product		

~ 500-600 kg/kg (https://doi.org/10.1016/j.scitotenv.2019.03.211)		
Ecological footprint: m^2 used/ kg final product from 2.5 to 1.6 m^2/t (considering field vegetables such as: Cabbage, Onions, Carrots, Beetroot, Tomatoes as a substrate for production. yields of field vegetables are from 30 to 40 t/ha and biogas/fertilizer yield from vegetables is about 400 m^3/t)		

8.2 Sustainability indicators for Value Chain – corn and wheat straws / biogas, organic fertilizer and animal feed

Table 12 Indicators evidenced for corn and wheat value chain – POLAND – PP5 PP6

ENVIRONMENT	SOCIETY	ECONOMY
Water footprint: volume of H_2O consumed/kg of final product Biogas 1300 – 2200 L/kg (doi: 10.1016/j.jclepro.2015.03.084) Organic fertilizer 1300 – 2200 L/kg Animal feed 1200 L/kg (Mekonnen, M.M. and Hoekstra, A.Y. (2011) The green, blue and grey water footprint of crops and derived crop products, Hydrology and Earth System Sciences, 15(5): 1577-1600.)	**n. of employees of bioeconomical sector/total number of employees working on territory** 175.3 k / 867,8 k (https://datam.jrc.ec.europa.eu/datam/mashup/BIO_REG_EU/)	**kg by-product/kg final product** 20% biogas 20% fertilizer 100% animal feed
Food miles: km supply distance/kg final product 0.014 km/m^3 (considering 12 000 kg of biomass per single transport, 50 km distance from supplier to production site; Biogas yield is estimated as 300 m3/t biomass)	**% share represented by the bioeconomic sector: n.** 20.2% (https://datam.jrc.ec.europa.eu/datam/mashup/BIO_REG_EU/)	**CEI index: value of the material produced/value of the original material** 48% biogas 3.5% fertilizer 13% animal feed
Cumulative Energy demand: KWh/kg of final product	**High profile employees (scientific degrees)/medium profile**	

2.8 kWh/m^3 (https://doi.org/10.1016/j.scitotenv.2019.03.211)	**employees along the value chain** 0.2-0.3	
Carbon footprint: kg CO_2 equiv/kg of final product biogas ~ 500-600 kg/kg (https://doi.org/10.1016/j.scitotenv.2019.03.211) fertilizer ~ 500-600 kg/kg (https://doi.org/10.1016/j.scitotenv.2019.03.211) Animal feed ~ 300-500 kg/kg		
Ecological footprint: m2 used/ kg final product from corn 2.9 m^2/t from wheat 11 m^2/t (considering corn as a substrate for production. Corn yields is 7 t/ha and biogas/fertilizer yield from corn is about 500 m^3/t) (considering wheat as a substrate for production. Wheat yields is 5 t/ha and biogas/fertilizer yield from corn is about 500 m^3/t)		

8.3 Sustainability indicators for Value Chain – corn rachis / biogas and organic fertilizer

Table 13. Indicators evidenced for corn rachis value chain – POLAND – PP5 PP6

ENVIRONMENT	SOCIETY	ECONOMY
Water footprint: volume of H_2O consumed/kg of final product Wheat: 1827 L/kg Corn: 1222 L/kg (Mekonnen, M.M. and Hoekstra, A.Y. (2011) The green, blue and grey water footprint of crops and derived crop products, Hydrology and Earth System Sciences, 15(5): 1577-1600.)	**n. of employees of bioeconomical sector/total number of employees working on territory** 175.3 k / 867,8 k (https://datam.jrc.ec.europa.eu/datam/mashup/BIO_REG_EU/)	**kg by-product/kg final product** 14% biogas 14% fertilizer
Food miles: km supply distance/kg final product 0.014 km/m^3 (considering 12 000 kg of biomas per single transport, 50 km distance from supplier to production site; Biogas yield is estimated as 300 m3/t biomas)	**% share represented by the bioeconomic sector:** n. 20.2% (https://datam.jrc.ec.europa.eu/datam/mashup/BIO_REG_EU/)	**CEI index: value of the material produced/value of the original material** 79% biogas 4.1% fertilizer
Cumulative Energy demand: KWh/kg of final product 2.8 kWh/m^3 (https://doi.org/10.1016/j.scitotenv.2019.03.211)	**High profile employees (scientific degrees)/medium profile employees along the value chain** 0.2-0.3	

Carbon footprint: kg CO_2 equiv/kg of final product biogas ~ 500-600 kg/kg (https://doi.org/10.1016/j.scitotenv.2019.03.211) fertilizer ~ 500-600 kg/kg (https://doi.org/10.1016/j.scitotenv.2019.03.211)		
Ecological footprint: m^2 used/ kg final product 2.9 m^2/t		

8.4 Sustainability indicators for Value Chain - Yellow mealworm larvae meal

ENVIRONMENT	SOCIETY	ECONOMY
Water footprint: volume of H_2O consumed/kg of final product 3,47 lt/kg final product doi:10.3390/w7116190 and own calculation	**n. of employees of bioeconomical sector/total number of employees working on territory** 2,4 Million empoloyees in BE in Poland 14% of total employees working in Poland	**kg by-product/kg final product** 4,40 kg/kg own calculation and data from D1.4.
Food miles: km supply distance/kg final product 0,024 km//kg final product own calculation	**% share represented by the bioeconomic sector:** 159 billion Euro turnover in BE in Poland 66.000 Euro turnover per person employed in bioeconomy in Poland	**CEI index: value of the material produced/value of the original material** 19,3 own calculation and data from D1.4.
Cumulative Energy demand: KWh/kg of final product	**High profile employees (scientific degrees)/medium profile**	

39,25 kWh/kg final product https://doi.org/10.1016/j.jclepro.2017.09.05	**employees along the value chain** About 20%	
Carbon footprint: kg CO_2 equiv/kg of final product 3,75 kgCO2/kg final product https://doi.org/10.1016/j.jclepro.2017.09.054		
Ecological footprint: m^2 used/ kg final product 0,00000413 km2/kg final product https://doi.org/10.1016/j.jclepro.2017.09.054		

10. Sustainability indicators for Austria Value Chains (PP8)

10.1 Sustainability indicators for Value Chain Pumpkin Seed Meal

Table 14. Indicators evidenced for pumpkin seeds/meal value chain – AUSTRIA – PP8

ENVIRONMENT	SOCIETY	ECONOMY
Water Footprint *volume of H2O consumed/kg of PSM* **3-8 l/kg** depending on the de-oiling process and/or the type of end product (partially or fully de-oiled)	EMPLOYMENT RATIO *no. of employees in bioeconomy sector/total number of employees working on territory* **2021** **3.793.100/193.352 (Austria)** **519.500/35.989 (Styria)**	**Input to Output Ratio** *kg by-product/kg final product* **100/80 - 100/90** *pumpkin seed cake/pumpkin seed flour or meal*
Food Miles *km supply distance/kg of PSM* **15-30 km/kg**	% SHAREOF THE BIOECONOMIC SECTOR *no. employees and turnover/no. employees and turnover general territorial economy* **employees (2021):** **5.1% (Austria)** **6.9% (Styria)** **turnover (2021):** **5.47% (Austria)** **9.55% (Styria)**	**Added Value** **Value Added Ratio (~~CEI~~): 12.2** *value of mat. produced/value of original mat.* **Value Added Ratio*: 8.2%** *value of original mat./value of produced mat.* **Added Value Ratio: 49.5%** *value of input mat./value of output mat.*
Cumulative Energy Demand *Kwh/kg of PSM* **4.35-8.35 kWh/kg**	IMPROVEMENT OF SOCIAL CAPITAL **As this value chain is based on traditional approaches,**	**Note** According to our understanding, the calculation of the Circular Economy Index (CEI) requires a set of indicators (such as

	recognisable increases in social capital are not readily apparent.	Resource Input Efficiency, Product Lifecycle Extension, Waste Management, Circularity in Production and Consumption, etc.) that are typically weighted differently. However, as these indicators have not been defined here, we have refrained from calculating a 'true' CEI.
Carbon Footprint *kg CO2 equiv/kg of PSM* **0.61-1.06 kg CO_2/kg**		
Ecological Footprint *Km2 used/kg of PSM* **ca. 0.0003298 km^2/kg**		

Sources:

- Hoekstra, A. Y., & Chapagain, A. K. (2007). *Water footprints of nations: Water use by people as a function of their consumption pattern*. Water Resource Management, 21(1), 35-48.
- *Mekonnen*, M. M., & Hoekstra, A. Y. (2011). *The green, blue and grey water footprint of crops and derived crop products*. Hydrology and Earth System Sciences, 15(5), 1577-1600.
- *Gerbens*-Leenes, P. W., Moll, H. C., & Schoot Uiterkamp, A. J. M. (2003). *Design and development of a measuring method for environmental sustainability in food production systems*. Ecological Economics, 46(3), 231-248.
- *Scalco*, A., Cesari, V., Salmaso, L., & Boscaini, A. (2021). *Water Quality Improvement through Biomanipulation Leads to Its Reuse in Agriculture: A Circular Economy Model*. Applied Sciences, 11(21), 10167. DOI: https://doi.org/10.3390/app112110167
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- *European* Food Information Council. (2015). Use of water in food production. Retrieved from https://www.eufic.org/en/food-production/article/use-of-water-in-food-production
- *Aibler* Ölpresse. (n.d.). In 5 Schritte zum Kernöl. Retrieved from https://www.aibler-oelpresse.at/ein-startseiten-abschnitt/
- *Steinhauser* Gut. (n.d.). Kürbis.Kern.Mehl. Retrieved from http://www.steinhausergut.at/steinhausergut/index.php/die-kernspezialitaeten/kuerbiskernmehl

11. Sustainability indicators for Slovensko Value Chain (PP9)

11.1 Sustainability of the Supply Chain based on hemp

Table 15. Indicators evidenced for hemp value chain – SLOVENJA – PP9

SUSTAINABILITY OF THE SUPPLY CHAIN		
ENVIRONMENT	**SOCIETY**	**ECONOMY**
Water footprint: volume of H_2O consumed/kg of final product **Hemcrete - 0,35** **Panel(dry) - 0** **Paper - 3** **3D mold - 0**	**n. of employees of bioeconomical sector/total number of employees working on territory** **2,47% employees in bioeconomic sector in Slovakia**	**kg by-product/kg final product**(evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) **Hemcrete - 100/100** **Panel(dry) - 100/98** **Paper - 100/95** **3D mold - 100/100**
Food miles: km supply distance/kg final product **Hemcrete - 1-100** **Panel(dry) - 1-100** **Paper - 1-100** **3D mold - 10-100**	**% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy** **2,22% turnover share in bioeconomic sector in Slovakia**	**CEI index: value of the material produced/value of the original material** (calculation of the Added Value) **Hemcrete - 5,6<<** **Panel(dry) - 5,7** **Paper - 9** **D mold - 10-20**
Cumulative Energy demand: KWh/kg of final product **Hemcrete - 0,1** **Panel(dry) - 0,1** **Paper - 0,5** **3D mold - 0,1**	**High profile employees (scientific degrees)/medium profile employees along the value chain** **Hemcrete - na** **Panel(dry) - na** **Paper - na**	
Carbon footprint: kg CO_2 eq./kg of final product **Hemcrete - -0,25** **Panel(dry) - 0**		

Paper - 0 **3D mold - 0** ***Ecological footprint:*** Km2 used/ kg final product **Hemcrete -** $2,78^{-6}$ **Panel(dry) -** $2,83^{-6}$ **Paper -** $4,76^{-6}$ **3D mold -** $3,33^{-5}$	**3D mold - na**	

NB: HEMP by-products are multiple, they can be classified as follows, depenmding on the technology used for preparation :
Hemcrete - Hemcrete is a “wet” technology that is researched and modified in terms of active ingredients and their ratios, as well as with local resources. These are modified filler and plaster mixtures that form a complete building system, with unique user features.
Panel (Dry) - The technology of pressed boards or panels from hemp shives is a “dry” way of hemp construction. Compared to the usual products, this product brings a lower weight and releases the ecological burden. We are looking on fully compostable binders so the boards can return to the biological cycle at the end of their lifespan.
Paper - Hemp hemicellulose paper is produced similarly to wooden paper, but with a significantly lower need for water and energy, as it has a lignin content of 8-10% (wood 20-30%). It resists decomposition and is recyclable multiple times compared to wooden paper. Challenge is special paper and its design use.
3D mold - Production with 3D printing takes place by melting plastic material in the form of a string, which passes through a nozzle and is gradually layered on the printing pad. By successive layering, an object of the desired shape is created. By replacing petrol-plastic with hemp biopolymer, we get a qualitatively completely new product.

12. Evaluation of sustainability indexes for the different value chains

Each partner has produced a comprehensive evaluation for each value chain considered under environmental, social and economic assets. Some partners have identified, considering the peculiarities of their regions/states, value chains common to others. In particular, the overall picture includes:

1. Grapes/wine value chain: ITALY PP1, PP3;
2. Grape pomace value chain: SLOVENIJA PP2;
3. Milk/diary value chain: ITALY PP1;
4. Apple value chain: ITALY, PP3;
5. Wood bark value chain: SLOVENIJA, PP2; GERMANY, PP4
6. Beer draff value chain: GERMANY, PP4;
7. Hemp value chain: GERMANY, PP4; SLOVENIJA, PP9
8. Rapeseed value chain: GERMANY, PP4;
9. Fruit and vegetables value chain: POLAND, PP5, PP6;
10. Corn and wheat value chain: POLAND, PP5, PP6;
11. Corn rachis value chain: POLAND, PP5, PP6;
12. Yellow mealworm larvae meal: POLAND; PP5, PP6
13. Pumpkin seed value chain: AUSTRIA, PP8;

As seen above, 13 different value chains were considered, and some partners have reported the same chain but with different indexes. In the following part of the report, results coming from the overall scenario will be compared and discussed, considering separately each value chain presented.

12.1 Environmental Indicators

With specific reference to environmental sustainability the following indexes were considered:

- **Water footprint**
- **Food miles**
- **Cumulative energy demand**
- **Carbon footprint**
- **Ecological footprint**

These 5 indixes are reported more or less in each value chain highlighted by each partner. Before making a comparison, it is advisable to define a shared value, where possible, for those chains common to multiple partners. As highlighted above, the chains in question are essentially that of wine, wood and hemp. The situation is shown in the following table.

Table 16. Environmental evaluation indexes reported by partner in common value chain

WINE VALUE CHAIN	ITALY – PP1	ITALY - PP3	AVERAGE VALUE ASSUMED FOR COMPARISON
Water footprint:	volume of H2O consumed/kg of final product 850 L water per L of wine (including irrigation) 2-4 L water per L of wine (only cellar production)	volume of H2O consumed/kg of final product 580 Lwater/bottle of wine (V=0.75 L) →773 Lwater/L wine (where the 95% of the total impact is for the upstream module) [1]	**volume of H2O consumed/kg of final product** **800 L water/bottle of wine**

Food miles	km supply distance/kg final product 0,018 km/liter of wine (considering 12000 kg of grapes per single transport, 15 km average distance from vineyard to cellar)	km supply distance/kg final product 0,0021 km/liter of wine 1.25 kg grape/L wine (considering 18 000 kg of grapes per single transport, 30 km average distance from vineyard to cellar) [3]	**km supply distance/kg final product** **0,012 km/liter of wine (*)** **(*)** **as weighted average starting from the two values reported**
Cumulative Energy demand:	Kwh/kg of final product 0.82 kWh/liter of wine	Kwh/kg of final product 0.24 kWh/liter of wine [1]	**Kwh/kg of final product** **0,6 kWh/ltier of wine (*)** **(*)** **cautelative**
Carbon footprint:	kg CO_2 equiv/kg of final product 1.1 -1.4 $kgCO_2$/liter of wine (85% coming from winemaking and bottling)	kg CO_2 equiv/kg of final product 1.07 $kgCO_2eq$/bottle of wine (V=0.75L) → 1.43 kgCO2eq/L [1]	**kg CO_2 equiv/kg of final product** **1.2 $kgCO_2eq$/liter of wine**
Ecological footprint:	m^2 used/ kg final product 1.5 m^2 / liter of wine * * calculated	m^2 used/ kg final product 12.5 ton grape/ha in South Tyrol [4] 1.25 kg grape/Lwine 1 m^2 / liter of wine * * calculated	**m^2 used/liter of wine** **1.25 m^2 used/lt of wine**

WOOD VALUE CHAIN	GERMANY – PP4	SLOVENIJA – PP2 (*) (*) Wood barks for tannin extraction	AVERAGE VALUE ASSUMED FOR COMPARISON
Water footprint:	volume of H_2O consumed/kg of final product wood: 366 L/kg [1]	The WF of wood for energy consumed (WF_{wec}) in the EU is 156×10^9 m^3/y (99% green; 1% blue) [4]	**volume of H_2O consumed/kg of final product** **366 l/kg (*)** (*) not comparable with these data
Food miles	km supply distance/kg final product wood: 0.004 km/kg [2]	km supply distance/kg final product 0.12 km/m^3 of sown wood distance up to 50 km; up to 30 m^3 of wood 5 m^3 sowing wood form 10 m^3 wood [5]	**km supply distance/kg final product** **0,01 km/kg (*)** (*) cautelative
Cumulative Energy demand:	Kwh/kg of final product 0 KWh/kg for wood waste [3]	3.98 kwh (based on tannin extraction from 1 kg dried bark) 173.05 kWh (based on the production of 1 kg of tannins) [1]	**Kwh/kg of final product** **3.98 kwh (based on tannin extraction from 1 kg dried bark)** **173.05 kWh** **(based on the production of 1 kg of tannins) (*)** **(*) Not comparable with these data.**

Carbon footprint:	kg CO_2 equiv/kg of final product 0.64 kg CO_2e/kg [4]	**1 m^3 of sawn softwood (RH: 70%)** Energy: 15.8 kg CO_2e Wood: 14.8 kg CO_2e Infrastructure: 3.06 kg CO_2e Transport, vehicle over 16 tonnes: 6.08 kg CO_2e **TOTAL: 39.8 kg CO_2e** **1.64 m^3 of Slovenian sawn softwood (RH: 70%)** Fuel consumption (diesel) for machinery: 4.9 kg CO_2e Chainsaw: 6.4 kg CO_2e Site preparation: 3.5 kg CO_2e TOTAL: 14.8 kg CO_2e [2]	**kg CO_2 equiv/kg of final product** **15-40 kg CO_2e (*)** **(*) Not fully comparable with these data.**
Ecological footprint:	Km^2 used/ kg final product Wood: 1.5 x 10^{-6} km^2/kg [5]	Not given	**Km^2 used/ kg final product** **1.5 x 10^{-6} km^2/kg wood**
HEMP VALUE CHAIN	GERMANY - PP4	SLOVENIJA - PP9	AVERAGE VALUE ASSUMED FOR COMPARISON
Water footprint:	volume of H_2O consumed/kg of final product Fibres: 2 719 L/kg [1] Shives: 3 987 L/kg Shives by mass balance of fibre value	volume of H_2O consumed/kg of final product **Hemcrete - 0,35** **Panel(dry) - 0** **Paper - 3** **3D mold - 0**	**volume of H_2O consumed/kg of final product** **Fibres: 2 719 L/kg** **Shives: 3 987 L/kg (*)** **(*) Not comparable with these data.**
Food miles	km supply distance/kg final product 4 x 10^{-3} km/kg [10]	km supply distance/kg final product Hemcrete - 1-100 Panel(dry) - 1-100	**km supply distance/kg final product**

		Paper - 1-100 3D mold - 10-100	**4×10^{-3} km/kg (*)** **(*)Not comparable with these data.**
Cumulative Energy demand:	Kwh/kg of final product Hemp: 4.95 kWh/kg [2] Fibres: 1.49 kWh/kg Shives: 2.77 kWh/kg Fibres and shives by mass balance of hemp value	Kwh/kg of final product Hemcrete - 0,1 Panel(dry) - 0,1 Paper - 0,5 3D mold - 0,1	**Kwh/kg of final product** **Hemp: 4.95 kWh/kg [2]** **Fibres: 1.49 kWh/kg** **Shives: 2.77 kWh/kg (*)** ***(*) cautelative, not fully comparable***
Carbon footprint:	kg CO2 equiv/kg of final product Hemp: 0.975 kg CO2e/kg [2] Fibres: 0.293 kg CO2e/kg Shives: 0.546 kg CO2e/kg Fibres and shives by mass balancing of hemp value	kg CO2 equiv/kg of final product Hemcrete - -0,25 Panel(dry) - 0 Paper - 0 3D mold - 0	**kg CO2 equiv/kg of final product** **Hemp: 0.975 kg CO2e/kg [2]** **Fibres: 0.293 kg CO2e/kg** **Shives: 0.546 kg CO2e/kg (*)** ***(*) cautelative, not fully comparable***
Ecological footprint:	Km2 used/ kg final product Per year, mass balance for cultivation: Fibres: 1.3×10^{-5} km^2/kg [3] Shives: 2.4×10^{-5} km^2/kg	Km2 used/ kg final product Hemcrete - $2,78^{-6}$ Panel(dry) - $2,83^{-6}$ Paper - $4,76^{-6}$ 3D mold - $3,33^{-5}$	**Km2 used/ kg final product** **Fibres: 1.3×10^{-5} km^2/kg** **Shives: 2.4×10^{-5} km^2/kg (*)** ***(*) cautelative, not fully comparable***

As it can be seen, due to the lack of homogeneity of the databases considered by the various partners, it is possible to obtain an average value only for the wine supply chain, the most homogeneous both in terms of territory and in terms of the database used. For the other two, wood and hemp, determining an average value attributable to the supply chain is difficult. In those cases, the value expressed by the partner was therefore used as a guide and was presented with a unit of measurement comparable with the starting input.

Now, extending the comparative method to all the 12 value chains, the question becomes even more difficult, again due to the persistent lack of homogeneity in the expression of the data presented for each different value chain. The following table represents an attempt at comparison regarding each of the environmental parameters considered, therefore a matrix (assuming a single index value is used) of 12 x 5, therefore 60 overall values, which express the environmental situation for each of the value chain presented by the partners.

Table 17. Resume of the data collected by partners concerning environmental indexes.

VALUE CHAIN:	GRAPES/WINE	GRAPE POMACE	MILK/DIARY	APPLE	WOOD	BEER DRAFF	HEMP	RAPESEED	FRUIT/VEG.	CORN AND WHEAT	YELLOW MEALWORM LARVAE MEAL	CORN RACHIS	PUMPKIN SEEDS
PARTNER:	PP1, PP3	PP2	PP1	PP3	PP2, PP4	PP4	PP4, PP9	PP4	PP5, PP6	PP5, PP6	PP5,PP6	PP5, PP6	PP8
Water footprint:	800 l water/lt wine	733 lt water/lt final prod.	2.15-4.3 lt water/lt milk	700 ltwater/kg apple	366 ltwater/kg wood	3,13 l/kg	2719-4987 lt/kg final prod.	0-1783 lt water/kg	500-1000 l/kg	1200-2200 l/kg	3,47 l/kg	1200-1800 l/kg	3,8 l/kg
Food miles	0,012 km/lt wine	0,0046-0,0086 km/l wine	0,047 km/kg cheese	0,034 km/kg apple	0,01 km/kg	0,02 km/kg	4 x 10-3 km/kg final prod.	8 x 10-4 km/kg	0,014 km/m3	0,014 km/m3	0,024 km/kg	0,014Km/m 3	15-30 km/kg
Cumulative Energy demand:	0,6 kWh/lt wine	0,237 kWh/lt wine	3,,3 + 7,1 kWh/kg cheese	3,79 kWh/kg apple	173 kWh/kg tannins	0,25 kWh/kg	1,49-4,95 kWh/kg final prod.	7,4 kWh/kg	2,8 kWh/m3	2,8 kWh/m3	39,25 kWh/kg	2,8 kWh/m3	4,35-3,85 kWh/kg
Carbon footprint:	1,2 kgCO2/lt wine	1,057 kg CO2/lt wine	1,6 + 1,2 khCO2/kgcheese	0,20 kgCO2/kg apple	15-40 kgCO2/kg tannins	69,93 kgCO2/kg	0,293-0,975 kgCO2/kg final prod.	0,72-1,19 kgCO2/kg	500-600 kgCO2/kg	500-600 kgCO2/kg	3,75 kgCO2/kg	500-600 kgCO2/kg	0,61-1,06 kgCO2/kg
Ecological footprint:	1,15 m2/lt wine	18,6 m2/lt wine	0,39-0,79 m2/kg cheese	0,15 m2/kg apple	1,5 x 10-6 km2/kg wood	0,75 km2/kg	1.3-2.4 km2/kg final prod.	2 x 10-6 km2/kg	1,6-2,5 m2/t	2,9-11 m2/t	4,13 x 10-6 km2/kg	2,9 m2/t	0,0003298 km2/kg

As it can be seen, the reported indexes sometimes differ by orders of magnitude. This evidence does not necessarily imply that there is a lower value in chains that have certain high indexes, since, as already highlighted, much depends on the way in which the index is expressed in the specific value chain. Generally speaking, it can be observed that:

- **Water footprint:** the milk, beer, yellow worms and pumpkin seeds supply chains undoubtedly have significantly lower values than the other chains;
- **Food miles:** here the index varies greatly and is strongly affected by the cluster considered and geographical considerations, also from the minimum quantity foreseen for transport. At a first analysis, the best values seem to be linked to grape pomace, hemp, rapeseed;
- **Cumulative energy demand:** following this index, the cheapest supply chains from an energy point of view appear to be those of wine, grape pomace, apples and hemp.
- **Carbon footprint:** in terms of climate-changing emissions, the chains that appear to have the least impact are those linked to apples, hemp and rapeseed, even if several others are relatively very close in terms of emissions;
- **Ecological footprint:** in this case, the index is greatly affected by the type of initial product used, and therefore takes on less importance than other considerations. However, if we want to talk about the supply chain as a whole and its use of land, the winning chains in this respect would seem to be those of milk, rapeseed and above all pumpkin seeds.

As a first conclusion, the picture that emerges indicates a substantial convergence towards the supply chains linked to yellow worms, pumpkin seeds, wood and milk. However, this framework cannot be considered as a definitive reality and applicable indiscriminately from the context, as the specific territorial location and probably a deeper evaluation of the complete chain, which therefore also includes the transformation phases of the by-products (in some cases still examined completely absent) could lead to very different application conveniences.

13.2 Social Indicators

Considering the ***social aspects***, the indicators that can be used essentially concern employment:

- increase in territorial system employment, which is measured through the ratio between the number of employees in the bioeconomic sector and that of the territorial economy as a whole; it is the % share represented by the bioeconomic sector in terms of number of employees and turnover on the same values as the local economy as a whole;
- improvement of Social Capital, which is measured through the improvement of the qualification of employees along the value chain of bioeconomic supply chains compared to traditional ones.

In the following, each value chain is separtely considered concerning these poin of view.

13.2.1 GRAPES/WINE Value Chain

PP1
GRAPES/WINE

n. of employees of bioeconomical sector/total number of employees working on territory 100.000/2.200.000 0,045 (considering agriculture, food and beverage)
% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy Employes 4.5 % (bioeconomy on total) Turnover 3% (bioeconomy: 4.769 million € Total 165.786 million €)

High profile employees (scientific degrees)/medium profile employees along the value chain
Share of graduates in total food industry workers: about 18%. Share of graduates in total industry: about 15%

PP2

Grape pomace/ pectin and natural colorants

n. of employees of bioeconomical sector/total number of employees working on territory
N (C11-beverages industry, Slovenia, 2022): 1.696 N (C10, food industry, Slovenia 2022): 18.057 N (total empol, Slovenia 2022): 989036 [4]
1.696/989036 = 0.0017 0,17%
18.057/ 989036 = 0,018 1,8%

Percentage of share represented by the bioeconomic sector:

It varies from 4.5% in Veneto Region (ITALY), which takes into consideration the entire wine production chain, to 1.8% in Slovenia considering the specific chain of by-products of the treatment of pomace for the extraction of pectin and natural colorants and comparing the number of employed in the bioeconomic sector, to the number of those in the agrifood sector (this index drops to 0.17% if considered in relation to the beverage sector alone).

Qualification available along the value chain:

Work linked to the bioeconomic sector requires high specialization and professionalism often develops in parallel with new lines of research: from an economic as well as social point of view, the costs and impacts of research (projects, etc.) should also be taken into account.

For example, for the Veneto Region, the share of graduates in total food industry workers is around 18% and is three percentage points higher than the Share of graduates in total industry (around 15%).

12.2.2 MILK/DAIRY Value Chain

PP1

n. of employees of bioeconomical sector/total number of employees working on territory **UE** 1,76% of total number of agroindustry workforce **Italy** 2,1% of total number of agroindustry workforce **Veneto Region** 2,8% of total number of agroindustry workforce **Veneto Region n. of employees in bioeconomical sector of Milk/dairy produce**: 2,8% out of 6% of workers in the milk/dairy sector in Italy (n. of employees in Milk/dairy produce in Veneto Region is 6% of national employees in the milk/dairy sector)
% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy **UE** 1,76% of total number of agroindustry workforce **Italy** 2,1% of total number of agroindustry workforce **Veneto Region** 2,8% of total number of agroindustry workforce
High profile employees (scientific degrees)/medium profile employees along the value chain Share of graduates in total food industry workers: about 18%. Share of graduates in total industry: about 15%

Percentage of share represented by the bioeconomic sector:

In the **Veneto** Region the number of employees in specific bioeconomical sector of Milk/Dairy produce is represented by 2,8% of total number of workers in the milk/dairy workforce.

Qualification available along the value chain:

Work related to the bioeconomic sector requires high specialization. In Veneto Region the Share of graduates in total food industry workers is around 18% and is three percentage points higher than the Share of graduates in total industry (around 15%).

12.2.3. Fruit and vegetable Value Chain

PP3 IT
APPLE

n. of employees of bioeconomical sector/total number of employees working on territory **South Tyrol** 13 % of total number of agroindustry workforce (37 895 people in agriculture sector in the region; 269 512 tot employees in the region) >94% of cultivated soil are apple trees (ISTAT 2023)
% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy UE 1,76% of total number of agroindustry workforce **Italy** 2,1% of total number of agroindustry workforce **South Tyrol** 14% of total number of agroindustry workforce
High profile employees (scientific degrees)/medium profile employees along the value chain Share of graduates in total food industry workers: about 18%. Share of graduates in total industry: about 15%.

PP8 AT
Pumpkin Seed Meal

employment ratio **no. of employees in bioeconomy sector/total number of employees working on territory** **2021** 3.793.100/193.352 (Austria) 519.500/35.989 (Styria)

% shareof the bioeconomic sector **no. employees and turnover/no. employees and turnover general territorial economy** **employees (2021):** 5,1% (Austria) 6,9% (Styria) **turnover (2021):** 5,47% (Austria) 9,55% (Styria)
Improvement of social capital As this value chain is based on traditional approaches, recognisable increases in social capital are not readily apparent

Percentage of share represented by the bioeconomic sector:

It varies from 14% in South Tyrol which considers the apple fruit and vegetable supply chain, to 5.1% in Austria and specifically to 6.9% in the Region of Styria for a very specific supply chain which is that of the processing of pumpkin seeds.

Qualification available along the value chain:

For South Tyrol and the apple fruit and vegetable supply chain, the Share of graduates in total food industry workers is around 18% and is three percentage points higher than the Share of graduates in total industry (around 15%).

In the case of Styria and the processing of pumpkin seeds, there is a traditional production linked to a niche product which does not necessarily require university preparation.

12.2.4. Wood Value Chain

Wood bark/ tannins
PP2 SLO

n. of employees of bioeconomical sector/total number of employees working on territory **N (C16, wood industry, Slovenia 2022): 9935** **N (total empl, Slovenia 2022): 989036** **9935/989036 = 1%**

Wood
PP4 DE

- **n. of employees of bioeconomical sector/total number of employees working on territory**
  In wood and forestry:
  BY: 163900 [6]
  BW: 175.000 [7]

  Total:
  7 790 000 employees in Bavaria

  6 380 000 employees in Baden-Wuerttemberg

  Share: 0.024

- **% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy**

  31 Mrd Baden-Wuerttemberg
  44 Mrd Bayern

  BIP Bavaria: 768 469 Mio €
  BIP Baden-Wuerttemberg: 615 017 Mio €

  Share employees: 2.4 %
  Share turnover: 5.4 %

- **High profile employees (scientific degrees)/medium profile employees along the value chain**

  No data available

Percentage of share represented by the bioeconomic sector:

It varies from 1% in Slovenia which considers all workers in the forestry sector (but which in the analysis of the supply chain focuses on the processing of bark and the extraction of tannins), to 2.4% of workers in the forestry sector in the two regions (Bavaria and Baden Wuerttemberg) of Germany, calculated with respect to the total employed people of the two regions mentioned above.

There is no data available on qualification available along the value chain.

12.2.5. Beer Draff Value Chain

PP4 DE

n. of employees of bioeconomical sector/total number of employees working on territory 10000 employees in breweries in Bavaria 7 790 000 employees in Bavaria 6 380 000 employees in Baden-Wuerttemberg 1500 employees in breweries in Baden-Wuerttemberg **% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy** Breweries turnover in Bavaria: 2116,4 Mio € Breweries turnover in Baden-Wuerttemberg: 521,5 Mio € BIP Bavaria: 768469 Mio € BIP Baden-Wuerttemberg: 615017 Mio € Share employees: 0.08 % Share turnover: 0.19 % **High profile employees (scientific degrees)/medium profile employees along the value chain** No data available

Percentage of share represented by the bioeconomic sector:

The beer sector in Germany in the two regions in question (Bavaria and Baden Wuerttemberg) records an employee share of 0.08%.

There is no data available on qualification available along the value chain.

12.2.6 Rapeseed Value Chain

PP4 DE

n. of employees of bioeconomical sector/total number of employees working on territory Employees in agriculture: BW 67 000 BY 113 900 Proportion: 0.013 **share of rapeseed oil of total oil produced in Germany:** 84 % **% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy** BY 5300 Mio € [8] BW 1600 Mio € [9] BIP Bavaria: 768 469 Mio € [10] BIP Baden-Wuerttemberg: 615 017 Mio € [10] Values Share employees: 1.28 % Share of turnover: 0.50 % **High profile employees (scientific degrees)/medium profile employees along the value chain** No data available

Percentage of share represented by the bioeconomic sector:

The rapeseed sector in Germany in the two regions in question (Bavaria and Baden Wuerttemberg) records a share of employees equal to 1.28% considering the ratio between the total employed in the rapeseed supply chain in the two regions and the total employed in the agricultural sector. Rapeseed oil represents 84% of the oil produced in Germany.

There is no data available on qualification available along the value chain.

12.2.7. Hemp Value Chain

PP4 DE

n. of employees of bioeconomical sector/total number of employees working on territory Employees in agriculture: BW 67 000 BY 113 900 No data available, the share of hemp industry of total industry is estimated to be significantly lower compared to rapeseed. 7 790 000 employees in Bavaria 6 380 000 employees in Baden-Wuerttemberg **share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy** BIP Bavaria: 768 469 Mio € BIP Baden-Wuerttemberg: 615 017 Mio € In agricultural sector: BY 5300 Mio € BW 1600 Mio € Values for agriculture: Share employees: 1.28 % Share of turnover: 0.50 %

High profile employees (scientific degrees)/medium profile employees along the value chain No data available

PP9 SK

n. of employees of bioeconomical sector/total number of employees working on territory **2,47% employees in bioeconomic sector in Slovakia** **% share represented by the bioeconomic sector: n. employees and turnover/ no. employees and turnover general territorial economy** **2,22% turnover share in bioeconomic sector in Slovakia** **High profile employees (scientific degrees)/medium profile employees along the value chain** **Hemcrete - na** **Panel(dry) - na** **Paper - na** **3D mold - na**

Percentage of share represented by the bioeconomic sector:

The hemp sector records an employee share of 1.28% in Germany in the two regions in question (Bavaria and Baden Wuerttemberg), while in Slovakia it is 2.4%.

There is no data available on qualification available along the value chain.

12.2.8 Wasted fruit and vegetable / Biogas and fertilizer Value Chain

PP5 e PP6 PL
Wasted fruit and vegetable / Biogas and fertilizer Value Chain

n. of employees of bioeconomical sector/total number of employees working on territory 175.3 k / 867,8 k
% share represented by the bioeconomic sector: n. 20.2%
High profile employees (scientific degrees)/medium profile employees along the value chain 0.2-0.3

12.2.9. Corn and Wheat straws / biogas, organic fertilizer and animal feed Value Chain

PP5 e PP6 PL
Corn and Wheat straws / biogas, organic fertilizer and animal feed

n. of employees of bioeconomical sector/total number of employees working on territory 175.3 k / 867,8 k
% share represented by the bioeconomic sector: n. 20.2%
High profile employees (scientific degrees)/medium profile employees along the value chain 0.2-0.3

PP5 e PP6 PL
Corn rachis / biogas and organic fertilizer

n. of employees of bioeconomical sector/total number of employees working on territory 175.3 k / 867,8 k
% share represented by the bioeconomic sector: n. 20.2%
High profile employees (scientific degrees)/medium profile employees along the value chain 0.2-0.3

12.2.10. Yellow mealworm larvae meal

PP5 e PP6 PL
Yellow mealworm larvae meal

n. of employees of bioeconomical sector/total number of employees working on territory 14%
% share represented by the bioeconomic sector: 159 billions Euro 66.000 Euro per person
High profile employees (scientific degrees)/medium profile employees along the value chain **About 20 %**

Percentage of share represented by the bioeconomic sector:

the treatment 1. Wasted fruit and vegetable / Biogas and fertilizer, 2. Corn and Wheat straws / biogas, organic fertilizer and animal feed, record an employee share of 20.2% in the two Polish regions analysed.

Qualification available along the value chain:

The High profile employees (scientific degrees)/medium profile employees ratio along the value chain is 0.2-0.3.

The next table represent the overall scenario considering social index as n. of employees of bioeconomical sector/total number of employees working on territory.

Table 18. Over situation considering n. of employees of bioeconomical sector/total number of employees working on territory.

Value Chain	Partners involved		Social Sustainability indicators
GRAPES/WINE	PP1 IT - VA	GRAPES/WINE	4,5
	PP3 IT - Fraunhofer	GRAPES/WINE	0,0
	PP2 SLO - NIC	Grape pomace/ pectin and natural colorants	1,8
MILK/DAIRY	PP1 IT - VA	MILK/DAIRY	2,8
Fruit and Vegetable	PP3 IT - Fraunhofer	Apple	14,0
	PP8 AT - CUAS	Pumpkin Seed Meal	6,9
Wood	PP2 SLO - NIC	Wood bark/ tannins	1,0
	PP4 DE - CCB	Wood	2,4
Beer Draff	PP4 DE - CCB	Beer Draff	0,1
Rapeseed	PP4 DE - CCB	Rapeseed	1,3
Hemp	PP4 DE - CCB	Hemp	1,3
	PP9 SK - SUA	Hemp	2,4
Vasted Fruit and Vegetable/Biogas and Fertilize	PP5 e PP6 PL - UWM e KPV	wasted fruit and vegetable / Biogas and fertilizer	20,2
Wheat straws/Biogas, Organic Fertilizer and An	PP5 e PP6 PL - UWM e KPV	corn and wheat straws / biogas, organic fertilizer and animal feed	20,2
	PP5 e PP6 PL - UWM e KPV	corn rachis / biogas and organic fertilizer	20,2
	PP5 e PP6 PL - UWM e KPV	yellow worms larvae meal	14,0

The situation can be more clear if a graphic approach is given as can be seen in the following picture. Poland seems to be the part of EU territory in which BE is much more present, considering this index.

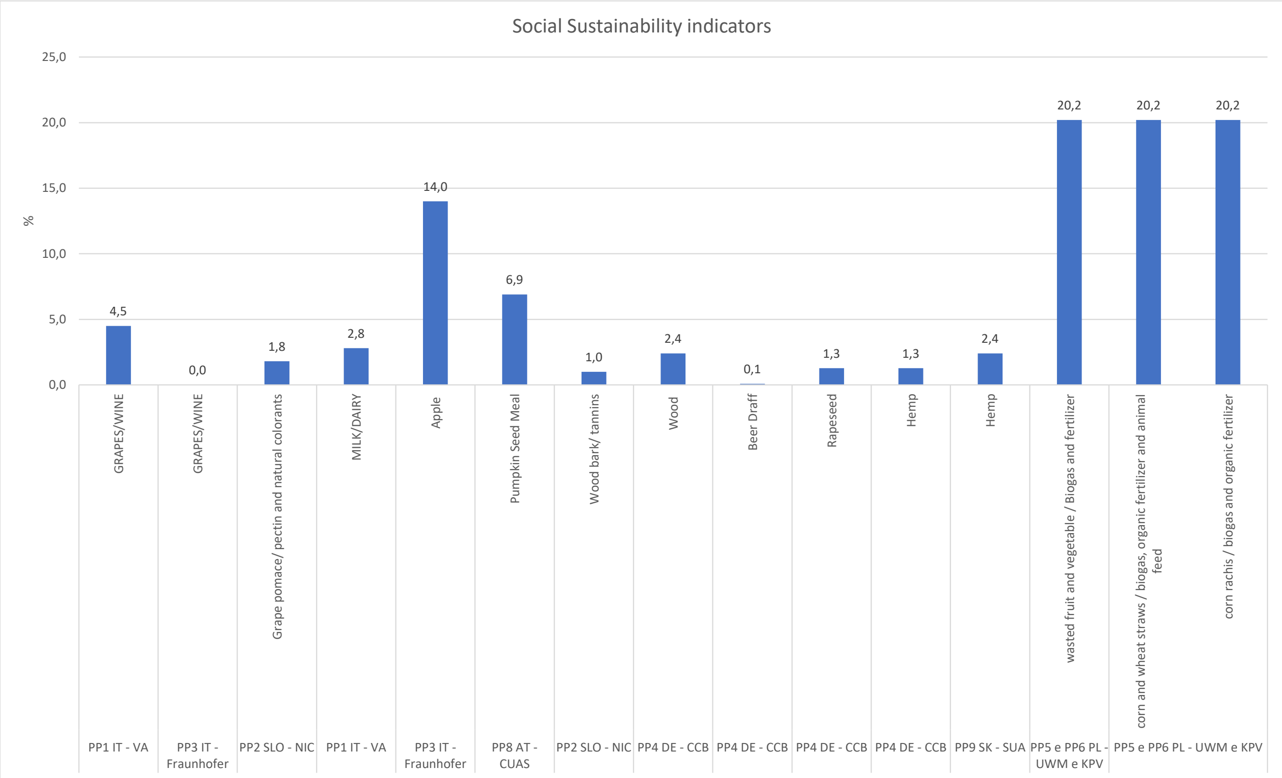

Figure 1. Overall social situation considering n. of employees of bioeconomical sector/total number of employees working on territory.

13.3 Economic Indicators

As regards the ***economic aspects***, the indicators that can be used refer to:

- contribution to circularity: kg of by-product/kg of final product used (quantifiable through the cost value: missed raw material purchase costs; missed waste management costs; production costs of the valorised product, secondary raw material compared to the traditional product);
- CEI Index: value of the material produced/value of the source material (calculation of the Added Value along the value chain).

13.3.1 GRAPES/WINE Value Chain

PP1

kg by-product/kg final product (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product 0.25 kg by product (lees and vinasses) per kg of grape treated or 0.35 kg by product (lees and vinasses) per liter of wine **CEI index: value of the material produced/value of the original material** (calculation of the Added Value) Ethanol: 0.028 €/kg vinasses Tartaric Ac: 0.585 €/kg vinasses Polyphenols: 1.75 €/kg vinasses Vinasses 12 €/100 kg (0.12 €/kg) CEI Ethanol: 0.25 Tartaric Acid: 4.87 Polyphenols: 14.58

PP3

kg by-product/kg final product (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product 1.25 kg grape/Lwine 0.3 kg grape pomace/kg grape **CEI index: value of the material produced/value of the original material** calculation of the Added Value) **By product**: Grape pomace (GP) 150 €/ton (0.15 €/kg) (assumption to be confirmed) **End products [2]** Costs: • Polyphenols: 20 €/kg • Grape seed oil 4 €/kg • Biochar 2.5 €/kg Yield: • 40.6 kg Polyph/ton GP • 49.7 kg grape seed oil/ton GP • 161.7 kg Biochar/ton GP **CEI** Polyphenols: 5.4 Grape seed oil: 1.3 Biochar: 2.7

PP2 SLOVENIA NIC

kg by-product/kg final product (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) **30 kg grape pomace/100 kg of grape / 70 L of wine** **0.7 L wine/1 kg grape** **0.3 kg grape pomace/1 kg grape** **1.43 kg grape/ L of wine** **CEI index:** **value of the material produced/value of the original material** (calculation of the Added Value) **by-product:** **Grape pomace: 200** **Red grape pomace :300 €/t** (estimation) New product: **Grape pectin: 50-70 €/kg** (estimation) **Natural colors: 50-150 €/kg** (estim.) **Yield of new product:** Pectin = 10 % (estimated average)[5] 10 kg pectin/100 kg grape pomace Natural color = 0.1 % (average)[6] 0.2kg natural color/ 100 kg red grape pomace **CEI (grape petcin) = 2.9 - 6 %** **CEI (grape natural colour) = 20-60 %**

13.3.2. MILK/DAIRY Value Chain

PP1

kg by-product/kg final product (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product 0.95 l by product (whey)/l milk treated 0,80 l scald/l milk treated 12 g proteins/ l whey used 4,5 g sugars recovered/l whey used
CEI index: value of the material produced/value of the original material (calculation of the Added Value) 3.0-4.85 euro/kg (proteins average price) 12,75 euro/1000 kg whey (2024) CEI = 2,8-4,6

13.3.3. Fruit and vegetable Value Chain

APPLE
PP3 IT

kg by-product/kg final product (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) 0,195 g pectin/kg apple pomace (fresh) 164 g pectin/kg apple pomace (dried)
Pectin: 10 €/kg [6] Apple pomace 0,0015 €/kg [10] CEI Pectin: 130

Pumpkin Seed Meal
PP8 AT

Input to Output Ratio *kg by-product/kg final product* **100/80 - 100/90** *pumpkin seed cake/pumpkin seed flour or meal*
Added Value **Value Added Ratio (~~CEI~~): 12,2** *value of mat. produced/value of original mat.* **Value Added Ratio*: 8,2%** *value of original mat./value of produced mat.* **Added Value Ratio: 49,5%** *value of input mat./value of output mat.*
Note According to our understanding, the calculation of the Circular Economy Index (CEI) requires a set of indicators (such as Resource Input Efficiency, Product Lifecycle Extension, Waste Management, Circularity in Production and Consumption, etc.) that are typically weighted differently. However, as these indicators have not been defined here, we have refrained from calculating a 'true' CEI.

13.3.4. Wood Value Chain

Wood bark/ tannins
PP2 SLO

kg by-product/kg final product (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) **2 m^3 wood bark/ 10 m^3 wood (logs)** **(bark = 20 % of logs)**
CEI index: value of the material produced/value of the original material (calculation of the Added Value) **by-product:** wood bark and wood of low quality: **price: 70 €/t = 0.070€/kg** New product: **Tannin extract: 65 €/kg** (estimation, for wine aplication) **Yield of new product:** Tanin = 6 % (estimated average) 6 kg of tannins /100 kg of bark **CEI (tanin) = 1.8 %**

Wood
PP4 DE

kg by-product/kg final product (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) No data available **CEI index: value of the material produced/value of the original material** (calculation of the Added Value) > 4 [10]

13.3.5. Beer Draff Value Chain

PP4 DE

- **kg by-product/kg final product** (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product)

  Biochar:
  1 kg beer draff (wet)/0.133 kg biochar [8]

  Biopackaging:
  1 kg beer draff (wet)/0.250 kg packaging

  [estimate based ob dry mass, addition of additives (10%) and loss during process (10%)]

- **CEI index: value of the material produced/value of the original material** (calculation of the Added Value)

  Biochar: 1600/56 = 28.6

  Biopackaging: 2500/56 = 44.6

  Based on wet draff and estimated value according to D.1.4

13.3.6. Rapeseed Value Chain

PP4 DE

kg by-product/kg final product (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) In case of direct use (without extraction steps): 1 **CEI index: value of the material produced/value of the original material** (calculation of the Added Value) In case of direct use (without extraction steps): 1

13.3.7. Hemp Value Chain

PP4 DE

kg by-product/kg final product (evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) Hempshives: hemp-biocomposites 75% hempshives for concrete = ¾=0.75 [8] Hempfibres: hemp-textiles: 0.8 90% of hempfibres (cellulose + semicellulose) are usedful for textile, 10% lost in processing [9] **CEI index: value of the material produced/value of the original material** (calculation of the Added Value) textile: 30 €/running metre / 200 €/ton Hemp composite: 21.2

PP9 SK

kg by-product/kg final product(evaluable through the cost value: lost raw material purchase costs; missed waste management costs; production costs of the valorised product (secondary raw material compared to the traditional product) **Hemcrete - 100/100** **Panel(dry) - 100/98** **Paper - 100/95** **3D mold - 100/100** **CEI index: value of the material produced/value of the original material** (calculation of the Added Value) **Hemcrete - 5,6** **Panel(dry) - 5,7** **Paper - 9** **3D mold - 10-20**

13.3.8. Wasted fruit and vegetable / Biogas and fertilizer Value Chain

PP5 e PP6 PL

kg by-product/kg final product
46% biogas 46% fertilizer
CEI index: value of the material produced/value of the original material
11% biogas 1,8% fertilizer

13.3.9. Corn and Wheat straws / biogas, organic fertilizer and animal feed Value Chain

PP5 e PP6 PL
Corn and Wheat straws / biogas, organic fertilizer and animal feed

kg by-product/kg final product
20% biogas 20% fertilizer 100% animal feed
CEI index: value of the material produced/value of the original material
48% biogas 3.5% fertilizer 13% animal feed

PP5 e PP6 PL
Corn rachis / biogas and organic fertilizer

kg by-product/kg final product
14% biogas 14% fertilizer
CEI index: value of the material produced/value of the original material
79% biogas

4.1% fertilizer

Considering the above scenario, a particular attention can be given to CEI index, which can be considered the main indicator concerning economic aspects. In the next table the complete situation of the overall basini s showed.

11.3.10. Yellow mealworm larvae meal

PP6, PP6 PL

Yellow mealworm larvae meal

kg by-product/kg final product
4,40 kg/kg
CEI index: value of the material produced/value of the original material
19,29

Table 19. CEI index for each situation.

Value Chain	Partners involved		CEI
GRAPES/WINE	PP1 IT - VA	ethanol	0,25
		tartaric acid	4,87
		polyphenols	14.58
	PP3 IT - Fraunhofer	polyphenols	5,40
		grape seed oil	1,30
		biochar	2,70
	PP2 SLO - NIC	Grape pectin	2,90
		Grape natural colorants	20,00
MILK/DAIRY	PP1 IT - VA	MILK/DAIRY proteins	2,80
Fruit and Vegetable	PP3 IT - Fraunhofer	Apple pectin	130,00
	PP8 AT - CUAS	Pumpkin Seed Meal	12,20
Wood	PP2 SLO - NIC	tanin	1,80
	PP4 DE - CCB	Wood	4,00
Beer Draff	PP4 DE - CCB	biochar	28,60
		biopackaging	44,60
Rapeseed	PP4 DE - CCB	Rapeseed	1,00
Hemp	PP4 DE - CCB	Hemp composite	21,20
	PP9 SK - SUA	Hemp/ Hemcrete	5,60
		Hemp/ Panel	5,70
		Hemp/ Paper	9,00
		Hemp/ 3D mold	10,00
Wasted Fruit and Vegetable/Biogas and Fertilizer	PP5 e PP6 PL - UWM e KPV	wasted fruit and vegetable / Biogas	11,00
		wasted fruit and vegetable / fertilizer	1,80
and Wheat straws/Biogas, Organic Fertilizer and Animal	PP5 e PP6 PL - UWM e KPV	corn and wheat straws / biogas	48,00
		corn and wheat straws / organic fertilizer	3,50
		corn and wheat straws / animal feed	13,00
		corn rachis / biogas	79,00
		corn rachis / organic fertilizer	4,10
		yellow mealworm larvae meal	19,29

As it can be seen, there are some important increase in value in few situation. The following picture emphasis in a better way the whole scenario.

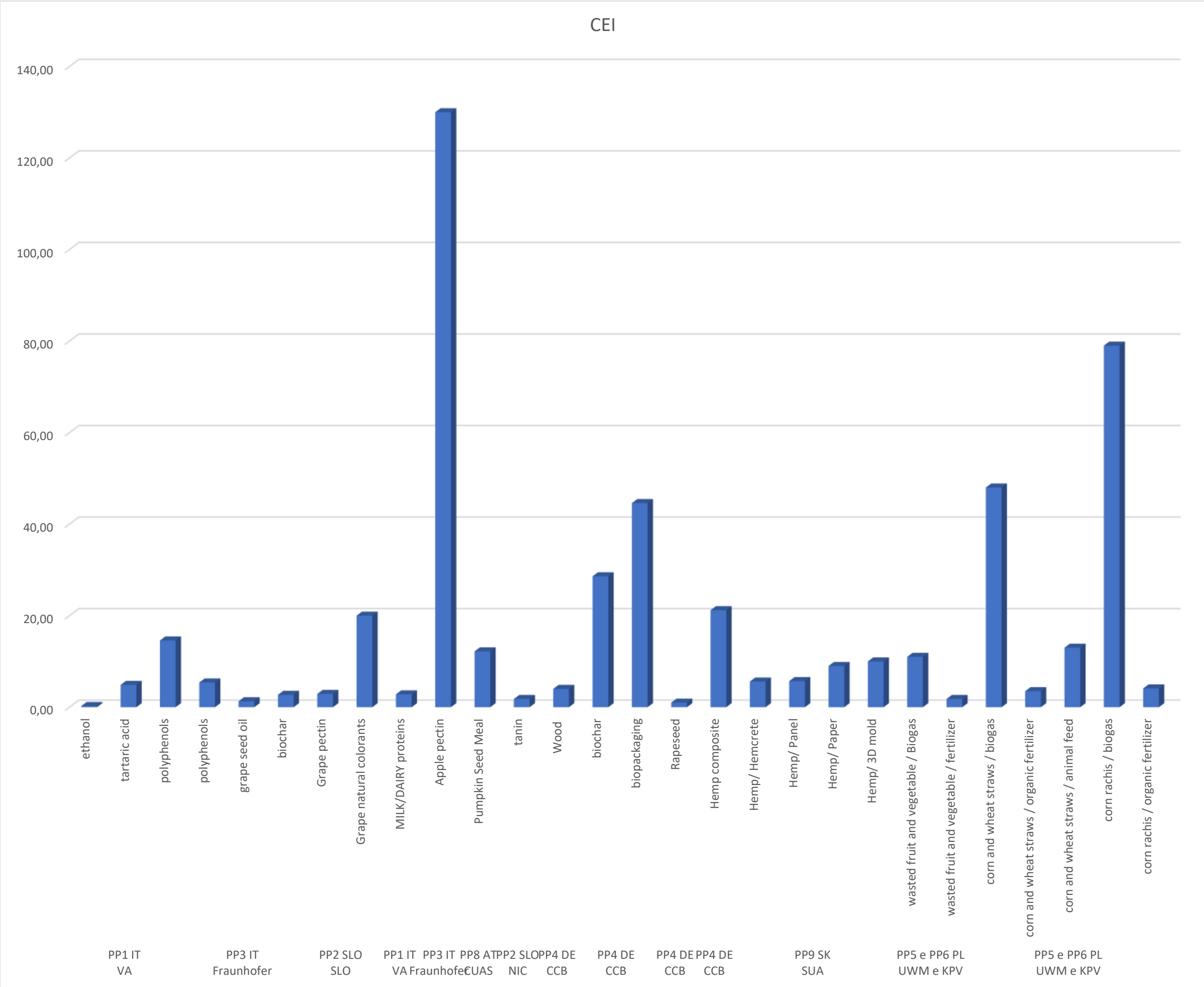

Figure 2. CEI representation for the whole scenario.

Values coming from apple chain as feed and biopackaging and biogas (from wheat etc.) shows indexes which are a lot important in value than the other chains.

In conclusion, it is considered important to highlight the potential and weaknesses that have characterized the analysis of the environmental, social and economic sustainability indices through a simple SWOT Analysis (Strengths, Weaknesses, Opportunities, Threats Analysis), in such a way as to underline which aspects to take taken into consideration to implement the analysis of the value chains of agri-food supply chains in other territorial contexts and with similar and comparable potential.

Table 20: SWOT Analysis for Environmental, Social and Economic Indicators

POINTS OF STRENGHTS	POINT OF WEAKNESS	OPPORTUNITY	THREATS
Systemic analysis perspective	Obsolete database and sources that do not communicate with each other	Analysis system replicable on other European territories and on similar value chain	Effects of large-scale phenomena not taken into consideration by specific indexes
	Lack of analysis and knowledge of consumer behavior for some products	Traceability of by-product and their potential to be able to organize the market and commercial management	Different perception of the development of value chains by public stakeholders
		Mapping of value chain in a systemic manner with comparison indexes and possibility of integration into the general territorial phenomena	

Annex 1 - Austrian partner in-depht analysis concerning environmental impacts

Water Footprint

PSM = pumpkin seed meal

Process	Water Footprint	Cumulative Energy Demand
grinding	0,5 - 2,0 l/kg	1,0 - 2,0 kWh/kg
drying	0,1 - 0,5 l/kg (energy generation not included)	2,0 - 4,0 kWh/kg
additional milling	0,5 - 2,0 l/kg	0,5 - 1,0 kWh/kg
de-oiling	1,0 - 3,0 l/kg (depending on the method used)	0,2 - 0,5 kWh/kg
sieving	< 0,5 l/kg	ca. 0,1 kWh/kg
packaging	< 0,5 l/kg	ca. 0,2 kWh/kg
storage	not directly attributable (depending on storage conditions)	ca. 0,05 kWh/kg
transport	not directly attributable (depending on transport/ distance)	0,3 - 0,5 kWh/kg
TOTAL	**3 - 8 l/kg PSM**	**4,35 - 8,35 kWh/kg PSM**

Sources:

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> *Scalco*, A., Cesari, V., Salmaso, L., & Boscaini, A. (2021). *Water Quality Improvement through Biomanipulation Leads to Its Reuse in Agriculture: A Circular Economy Model*. Applied Sciences, 11(21), 10167. DOI: https://doi.org/10.3390/app112110167

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Food Miles

The approximation was made on the basis of average values and some plausible assumptions:

Origin: The pumpkin seed cake comes from the production of pumpkin seed oil in Austria.

Processing: The pumpkin seed cake is processed into flour in an Austrian mill.

Packaging: Packaging materials come from Austria.

Transport: Pumpkin seed cake may be transported to the mill; finished pumpkin seed flour/meal is distributed domestically.

Estimated food miles average:

1. Average supply distance in Austria: 300 km
2. Total distance per year for the amount 3.000 kg:

assuming each delivery includes 10-20 kg, there would be 300-150 deliveries annually

the total distance traveled per year:

300 deliveries × 300 km = 90.000 km

150 deliveries × 300 km = 45.000 km

3. Calculation of Food Miles per kilogram:

Food Miles per kg of PSM:

= 90.000 km /3.000 kg = 30 km/kg

= 45.000 km /3.000 kg = 15 km/kg

⇨ **Food Miles: ca. 15-30 km/kg of PSM**

Cumulative Energy Demand

The energy demand for each stage can vary widely, but we use average values for typical food processing technologies involved in oilseed flour production.

A rough estimation for each process step:

1. Grinding: The grinding of the PSC to produce a coarse flour can consume about 1 to 2 kWh per kg of PSM.
2. Drying: Removing moisture from the crushed seeds is energy-intensive; it might consume approximately 2 to 4 kWh per kg, depending on the initial moisture content and the desired dryness level.
3. Additional Milling: Further milling to achieve the desired fineness of the flour typically consumes about 0.5 to 1 kWh per kg of input.
4. De-oiling: The mechanical pressing or solvent extraction for de-oiling can vary significantly; mechanical pressing might consume around 0,2 to 0,5 kWh per kg, while solvent extraction could be slightly more energy-efficient.
5. Sieving: is relatively less energy-intensive, estimated at about 0,1 kWh per kg.
6. Packaging: can vary but is generally low, estimated at about 0,2 kWh per kg.
7. Storage: primarily depends on the need for temperature and humidity control; for non-refrigerated storage, this would be minimal, ca. 0,05 kWh per kg per month.
8. Transport: can vary greatly depending on the distance and mode of transport; a rough estimate for local transport might be around 0.3 to 0.5 kWh per kg, depending on the actual distance covered (assumed average distance: 300 km).

⇨ **Cumulative Energy Demand: 4,35 – 8,35 kWh/kg PSM**

☝ Actual values can vary based on specific technologies used, operational efficiencies, and the actual process parameters.

Sources:

- Rosentrater, K. A., & Evers, A. D. (Eds.). (2018). *Kent's Technology of Cereals: An Introduction for Students of Food Science and Agriculture* (5th ed.). Woodhead Publishing.
- Worrell, E., & Galitsky, C. (2005). *Energy Efficiency Improvement and Cost Saving Opportunities for the Corn Wet Milling Industry: An ENERGY STAR Guide for Energy and Plant Managers*. Lawrence Berkeley National Laboratory.
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Carbon Footprint

- Carbon Intensity of Energy: 75% of electricity comes in Austria from renewable sources => have a very low carbon intesity, close to 0 kg CO2e/kWh; 25% that comes from non-renewable sources needs to be considered. Assuming a carbon intensity of non-renewable sources in Austria is about 0,45 kg CO2e per kWh (a typical value for a mix of fossil fuels), the average carbon intensity (average carbon emissions per kilowatt-hour of electricity consumed) can be estimated as:

- 0,25 x 0,45 kg CO2e/kWh + 0,75 x 0 CO2e/kWh = 0,1125 CO2e/kWh

- Energy Consumption: 4,35 to 8,35 kWh per kg of PSM
  - 4,35 kWh/kg × 0,1125 kg CO2e/kWh = 0,489375 kg CO2e/kg PSM
  - 8,35 kWh/kg × 0,1125 kg CO2e/kWh = 0,939375 kg CO2e/kg PSM

- Transport:
  - assumption:

    transport with small vans or buses (total freight: 610 kg) that use diesel

    distance: ca. 300 km x 300 = 90.000 km supply distance annually

    transported quantity: 3000 kg of PSM annually
  - diesel vans/buses emit ca. 0,25 kg CO2 per km driven
  - ⇨ (0,25 kg CO2/km x 90.000 km) = 22.500 kg CO2 annually (total freight)
  - 10 kg of PSM per trip, along with 600 kg of other goods
  - ⇨ proportion of PSM per trip: 10 kg PSM/610 kg ≈ 1,64% of cargo
  - ⇨ 22.500 kg CO2 x 1,64% = 369 kg CO2 annually for PSM
  - ⇨ 369 kg / 3000 kg = 0,123 kg CO2/kg PSM

Total Carbon Footprint

- 0,489375 kg + 0,123 kg = 0,612375 kg CO2/kg PSM
- 0,939375 kg + 0,123 kg = 1,062375 kg CO2/kg PSM

⇨ **Carbon Footprint: 0,612375 - 1,062375 kg CO2/kg PSM (average: 0,837375 kg CO2/kg)**

Source:

> Umweltbundesamt Österreich. (2022). Erneuerbare Energie. Retrieved, from https://www.umweltbundesamt.at/energie/erneuerbare-energie

Ecological Footprint

Key Parameters:

- Water Footprint: 3-8 liters/kg PSM.
- Food Miles: 15-30 km/kg PSM.
- Cumulative Energy Demand: 4,35-8,35 kWh/kg PSM.
- Carbon Footprint: 0,61-1,06 kg CO2 equiv/kg PSM.

- Water Consumption (production):
  - 5,5 litres/kg PSM (average of 3 and 8 litres); since water does not directly occupy land, we do not convert this value into km².
- Energy Consumption (production):
  - 6,35 kWh/kg PSM (the midpoint between 4,35 and 8,35 kWh)

- to calculate the land required for this energy, we assume that approximately 0,00005 km² per kWh is needed for energy generation (this is a rough estimate):

⇨ 6,35 kWh/kg × 0,00005 km²/kWh = 0,0003175 km²/kg PSM

- Transport:
  - 369 kg CO2 (previously calculated)
  - the land area required to absorb 369 kg CO2, is 0.0001 km²/kg CO2 (this is an assumption based on average sequestration rates of temperate forests):

⇨ (369 kg × 0,0001 km²/kg) / 3000 kg = 0,0000123 km²/kg

⇨ **Total Ecological Footprint**: 0,0003175 km²/kg + 0,0000123 km²/kg = **0,0003298 km²/kg**

Dependent employees in bioeconomical sector (ratio & percentage)

DEemp ... dependet employees

Austria

Year	#DEmp	#DEmp$_{bioec}$	#DEmp$_{bioec}$/#DEmp (%)
2019	3.825.400	186.209	4,87%
2020	3.772.100	187.585	4,97%
2021	3.793.100	193.352	5,10%
2022	3.899.500	?	
2023	3.941.200	?	

Styria

Year	#DEmp	#DEmp$_{bioec}$	#DEmp$_{bioec}$/#DEmp (%)
2019	532.500	35.153	6,60%
2020	515.300	35.874	6,96%
2021	519.500	35.989	6,93%
2022	?	?	
2023	?	?	

percentage share of dependent employees in the total labour force (Austria): 87%-87,5%

Sources:

> Forum Ökosozial. (2021). Wirtschaftsboom am Land: Bioökonomie machts möglich. Retrieved from https://oekosozial.at/wirtschaftsboom-am-land-biooekonomie-machts-moeglich/

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Year	Austria			Styria		
	t_{bioec} (€ mil.)	t (€ mil.)	t_{bioec} /t (%)	t_{bioec} (€ mil.)	t (€ mil.)	t_{bioec} /t (%)
2021	46.156	843.300	5,47%	7.510	78.665	9,55%

from https://www.bmaw.gv.at/newsletter/Newsletter-08-2023/Arbeitsmarkt.html

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Taxable turnover (t) in bioeconomical sector (% share)

Sources:

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Qualification available along the value chain

☝ The phrasing *"improvement of Social Capital, which is measured through the improvement of the qualification of employees along the value chain of bioeconomic supply chains compared to traditional ones"* is somewhat confusing for us, as the starting point, criteria and/or method for measuring the "improvement" were not clearly specified.

However, as the production methods used in this value chain are still based on traditional processes, recognisable increases in social capital, which can be measured by the improvement in employee qualifications, are not readily apparent

Input to Output Ratio

- Input: 1 kg pumpkin seed cake
- Output:
  - 0,06 - 0,08 kg oil
  - 0,05 - 0,10 kg water
  - 0,89 - 0,82 kg pumpkin seed flour/meal

Input-to-Output Ratio (kg by-product/kg final product): **100/80 to 100/90**

Added Value

Value Added Ratio

$$Value - Added\ Ratio = \frac{value\ of\ material\ produced\ (EUR/kg)}{value\ of\ original\ material\ (EUR/kg)}$$

a) Value of material produced:

- average sales price: 13,00 EUR/kg pumpkin seed meal
- 1 kg pumpkin seed cake yields min. 0,80 kg pumpkin seed flour (de-oiled) + 0,2 kg oil and water

⇨ value of material produced: 0,80 kg x 13,00 EUR/kg = **10,40 EUR**

b) Value of original material:

- average purchase price (0,70 EUR – 1,00 EUR) for 1 kg pumpkin seed cake: **0,85 EUR**

Value - Added Ratio: 10,40 EUR/kg / 0,85 EUR/kg = **12,24**

Value Added Ratio*

$$Value - Added\ Ratio *= \frac{value\ of original\ material\ (EUR/kg)}{value\ of\ material\ produced\ (EUR/kg)} \times 100$$

Value - Added Ratio*: (0,85 EUR/kg / 10,40 EUR/kg) x 100 = **8,17%**

Added Value Ratio

$$Added\ Value\ Ratio = \frac{value\ of\ input\ material\ (EUR/kg)}{value\ of\ produced\ material\ (EUR/kg)}$$

$$= \frac{sales\ price - (material\ costs + production\ costs)}{sales\ price}$$

measures the proportion of value generated from the manufacturing process, considering both the input material costs and the direct production costs; used for evaluating how effectively a company converts raw materials and labour into finished products that create additional market value

c) Average sales price:

- 13 EUR/kg

d) Purchase costs for pumpkin seed cake (material costs):

- pumpkin seed cake: 0,70 – 1,00 EUR/kg → average: 0,85 EUR/kg
- max. kg of pumpkin seed cake required to produce 1 kg of pumpkin seed meal:
  - 1/0,8 = 1,25 kg
  - 1,25 kg x 0,85 EUR/kg = 1,06 EUR

- packaging (grease proof paper bags): 0,20 – 0,30 EUR/pc → average: 0,25 EUR/pc

e) **Production costs:**

- Grinding
  - energy: 1,5 kWh/kg
  - in Austria, the average price for commercial energy: 0,27 EUR/kWh (2023)
  - ⇨ 1,5 kWh/kg x 0,27 EUR/kWh = 0,41 EUR/kg
- Drying
  - energy: 3,0 kWh/kg
  - ⇨ 3,0 kWh/kg x 0,27 EUR/kWh = 0,81 EUR/kg
- Additional milling
  - energy: 1,0 kWh/kg
  - ⇨ 1,0 kWh/kg x 0,27 EUR/kWh = 0,27 EUR/kg
- De-oiling (mechanical, without solvents)
  - energy: 1,5 kWh/kg
  - ⇨ 1,5 kWh/kg x 0,27 EUR/kWh = 0,41 EUR/kg
- Sieving
  - energy: 0,1 kWh/kg
  - ⇨ 0,1 kWh/kg x 0,27 EUR/kWh = 0,03 EUR/kg
- Packaging (process)
  - energy: 0,2 kWh/kg
  - ⇨ 0,2 kWh/kg x 0,27 EUR/kWh = 0,05 EUR/kg
- Storage
  - the costs can vary and depend on the duration and type of storage
  - we assume an additional energy cost due to storage: 0,05 kWh/kg
  - ⇨ 0,05 kWh/kg x 0,27 EUR/kWh = 0,01 EUR/kg

- **Water (inkl. waste water) costs:**
  - average price of 0,0027 EUR/l + 0,0025 EUR/l = 0,0052 ~ 0,005 EUR/l
  - consumed water + waste water throughout the entire process: ca. 10 l
  - ⇨ 10 l/kg x 0,005 EUR/l = 0,05 EUR/kg.
- **Transportation costs:**
  - emissions: 0,123 kg CO2/kg PSM
  - average cost of CO2 emissions (e.g., via carbon credits): 0,035 EUR/kg CO2
  - ⇨ 0,123 kg CO2/kg x 0,035 EUR/kg CO2 = 0,004305 EUR/kg.
- **Depreciation for machinery:**

- The calculation of depreciation depends on the lifespan of the machinery and the initial cost value; for a very rough estimate, we assume that the machines are depreciated over a period of 10 years
- we set an approximate value of 0,01 EUR/kg as depreciation

- **Labour costs:**
  - we would have to consider the average costs of technical staff in the food industry without a university degree; according to statistical data, the average costs for an employee (oil mill/machine operator, general labourer, etc.) in Austria could be around 30.000 - 35.000 EURO per year → average: 32.500 EUR/year
  - with a work productivity of ca. 10.000 kg of flour (pumpkin seeds and other seeds) per year (if one operates a smaller mill):
  - ⇨ 32.500 EUR/10.000 kg = 3,25 EUR/kg for one employee
- **Total costs**:
  - ⇨ 1,06 + 0,25 + 0,41 + 0,81 + 0,27 + 0,41 + 0,03 + 0,05 + 0,01 + 0,004 + 0,01 + 3,25 = **6,56 EUR/kg**

☝ This calculation is based on average values and assumptions, and actual costs may vary depending on energy prices, water costs, and specific processing conditions. Additional overhead costs, such as for maintenance, administration, marketing, insurance or rental costs, are not included in this calculation.

Added Value Ratio: (13 EUR/kg - 6,56 EUR/kg)/13 EUR/kg = 0,4954 = **49,54%**

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Circular Economy Index (CEI)

The Circular Economy Index (CEI) is a quantitative measure that evaluates how well a company or - in that case - a value chain adheres to the principles of a circular economy; it is calculated by identifying **relevant**

indicators within several key categories such as resource efficiency, waste management, and product lifecycle extension.

Example: Pumpkin Seed Flour/Meal Production

Value chain description

- Raw Material Recovery: Pumpkin seeds are pressed for oil, leaving pumpkin seed cake as a byproduct.
- Processing: The seed cake is dried and ground into fine pumpkin seed flour.
- Packaging: The flour is packaged in biodegradable containers.
- Distribution: Packaged flour is sold to retailers and directly to consumers.
- Usage: Consumers use the flour as a dietary supplement or a cooking ingredient.
- Recycling/Disposal: The biodegradable packaging is composted or recycled.

CEI calculation

Data for each indicator is normalized (on a scale from 0 to 1), and each category is weighted according to its importance before the scores are aggregated to produce the final CEI value.

Indicators and Weighted Scores:

- Resource Input Efficiency
    - Indicator: Utilization rate of the seed cake
    - Value: 95% utilization (0,95)
    - Weight: 30%
- Product Lifecycle Extension
    - Indicator: Product lifespan enhancement
    - Value: High-quality processing extends product use (0,8)
    - Weight: 20%
- Waste Management
    - Indicator: Rate of packaging recycling
    - Value: All packaging is compostable (1,0)
    - Weight: 25%
- Circularity in Production and Consumption
    - Indicator: Use of recycled materials in production
    - Value: Biodegradable packaging (0,9)
    - Weight: 15%
- Innovation and Circular Economy Promotion
    - Indicator: Investment in R&D for circular practices
    - Value: Low investment levels (0,3)
    - Weight: 10%

⇨ **CEI Score:** (0,95×0,3) + (0,8×0,2) + (1,0×0,25) + (0,9×0,15) + (0,3×0,1) =

(0,285) + (0,16) + (0,25) + (0,135) + (0,03)=**0,86**

The CEI score of 0,86 (on a scale of 0 to 1) indicates a robust integration of circular economy practices within the pumpkin seed flour/meal production chain.

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