INDICATORS AND METHODS FOR MEASURING TRANSITION TO CLIMATE NEUTRAL CIRCULARITY

Task 5: Case-study group B2

Report for: DG RTD, Directorate B – Healthy Planet, Unit B1: CE & Biobased Systems

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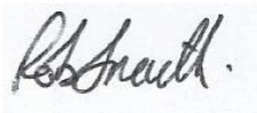

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1. INTRODUCTION

The transition to a Circular Economy (CE) needs to occur on multiple levels, from households and individual consumers to national and cross-border ecosystems. Measuring and monitoring the development of this transition is an ambitious task and is ideally supported by indicators relevant to all steps in that process.

This case-study is one of 19 developed for a research project into "*Indicators and methods for measuring transition to climate neutral circularity, its benefits, challenges and trade-offs*". It provides a detailed summary of the development and testing programme conducted for Group 2 of the bioeconomy sub-policy area during Task 5 of the project. The main purpose of this case-study is:

1. Provide an overview of the testing and monitoring method adopted for each indicator.
2. Outline the key results and performance of each indicator.
3. Highlight any challenges or lessons learnt from the identification, planning, delivery and analysis of the relevant methodology for each indicator.

The aim of Task 5 is to take the learnings of all other Tasks thus far and develop and test the new indicators identified in Tasks 3 and 4 as having potential to enable a deeper understanding of the 3 facets of circularity for the five key approaches. This case-study is a direct output of Task 5.

This case-study focuses on the following three indicators outlined in Table 1.

Table 1. Overview of case-study group 2

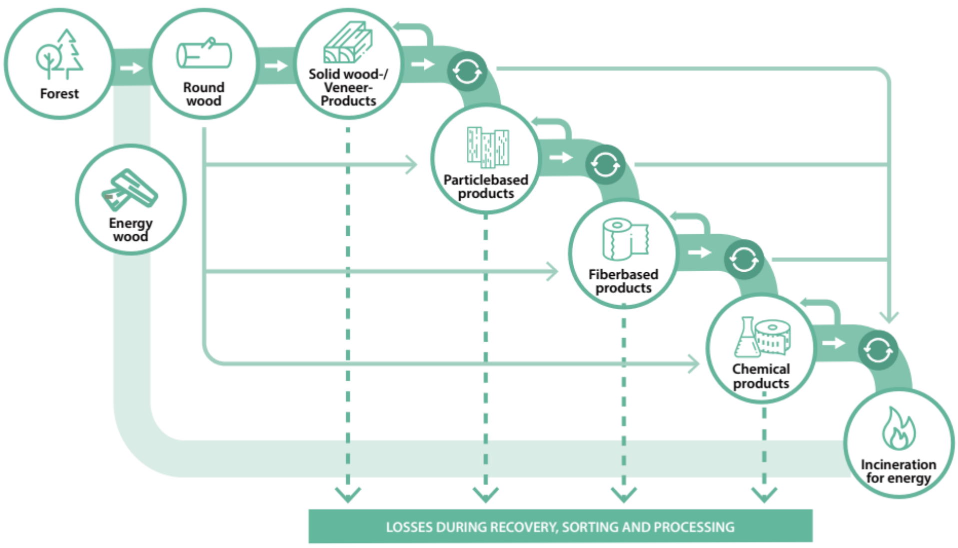
URN		Indicator name	Methodology	Level of implementation				
				EU	National	City / Region	Companies	Household
B2	**1**	Share of local forestry by-products going to energy generation	• Desk based research • Stakeholder engagement • Material flow analysis			X	X	
B3	**2**	Share of organic fertiliser used in agricultural practices	• Desk based research • Material flow analysis			X		
B8	**3**	Share of biological waste treated with anaerobic digestion	• Desk based research • Stakeholder engagement • Material flow analysis			X	X	

2. INDICATOR 1: SHARE OF LOCAL FORESTRY BY-PRODUCTS GOING TO ENERGY GENERATION

This indicator measures the share of local forestry by-products going to energy generation at both regional and company levels. The original indicator was the 'share of local forestry and agricultural waste by-products going to energy generation', however the decision was taken to amend it in January 2024 to focus on one industry to allow for a more accurate output and measure of circularity. Furthermore, the term 'waste' was removed from the indicator title after consultation with forestry industry stakeholders revealed that all by-products have a use and are not considered waste. A more detailed explanation of the deviation from the original indicator is outlined in Section 2.1.2.

Given the absence of a standardised definition for forestry by-products and the challenges in distinguishing between forestry products, co-products, by-products and residues (Vis M., 2016), this study adopted a definition based on the concept of cascading wood use by Hoglmeier et al. (Karin Höglmeier, 2015). This definition encompasses all wood-based products except solid or sawn wood including co-products such as particle or fibre-based boards, and residues such as chips, sawdust and bark (Table 2). It also includes liquid from the pulp industry such as black liquor or tall oil. Throughout the report, by-products and residues may be used interchangeably as if residues have a market value, they are classified as by-products (Vis M., 2016).

Figure 1: The cascading use of wood adapted from Hoglmeier et al. (2015)



Note: Round wood: Uncut or unprocessed timber in its natural cylindrical form / Energy Wood: Wood specifically harvested for energy production. / Fuel Wood: Wood used as primary source of fuel i.e., burned for heat. / Industry wood: Wood utilised for industrial purposes such as construction. / Unused wood: Wood that has not been utilised or processed for any specific purpose.

This indicator must be considered alongside the principles of Sustainable Forestry Management[1] (SFM) and the cascading use of wood. Research carried out on greenhouse gas emissions produced from bioenergy indicates that burning biomass initially creates a rise in carbon emissions, which is only balanced by forest regeneration and the displacement of fossil fuels (Duncan Brack, 2021).

For this reason, from a circularity and resource-efficiency perspective, the aim of the indicator is not to increase the share of forestry by-products going to energy generation. Bioenergy production should only be considered as part of the cascading and resource-efficient use of wood (Figure 1). Unlike some metals or glass which can be recovered and transformed into similar quality materials, once wood has been transformed, it usually cannot be reprocessed into the same quality as the original roundwood (UNECE & FAO, 2021). Therefore, the aim to develop as many products and value streams as possible, before the wood is eventually recovered for energy

[1] European Environment Agency, Sustainable Forest Management <https://www.eea.europa.eu/help/glossary/eea-glossary/sustainable-forest-management> [Accessed February 2024]

when further utilisation is not possible, or feasible (Odegard, 2012). This way, the embodied carbon in wood remains sequestered for as long as possible.

Table 2: Examples of wood products and by-products adapted from (Vis M., 2016)

Product	Co-product	Residues
Sawn wood	Particle-based products	Chips
	Fibre-based products	Sawdust
		Bark
		Black liquor
		Tall oil

This indicator has been selected to measure circularity in the bioeconomy, because the by-products created by the forestry and woodworking industries can be used to produce bioenergy, which is a considered a resource-efficient use of residues (UNECE & FAO, 2021). The Joint Wood Energy Enquiry (JWEE) revealed that in 2019 wood energy accounted for 34.6% of the renewable energy supply in the UNECE region, making it the leading source of renewable energy (UNECE & FAO, 2017). Based on data from 12 countries (Austria, Cyprus, Finland, France, Germany, Ireland, Luxembourg, Serbia, Slovenia, Sweden, Switzerland and the UK), wood energy consumption increased by 37% from 2007 to 2017. This sharp increase is predominantly driven by renewable energy policies, such as the Renewable Energy Directive (RED), which encourages reduced dependency on fossil fuels.

There are many benefits to monitoring this indicator, for example:

- Monitoring performance against the RED.
- Ensuring the resource efficiency of wood.
- Highlighting the role of sustainable forestry in the EU's energy mix.
- Encouraging better data collection on the uses of forestry by-products, which could facilitate more informed policymaking and help policymakers identify best practice.

2.1 KEY METHODOLOGY

2.1.1 Testing method

This indicator is measured at a regional level, limited to the regions of Bavaria in Germany and South Savo in Finland, and at a company level, limited to the Bavarian State Forest Enterprise (BaySF).

- Bavaria was selected because Germany produced the highest levels of renewable energy derived from solid biofuels in 2021 and 2022 (EurObserver, 2022), and Bavaria is a region with one of the largest forested areas in Germany (37%) (BMEL, 2015).
- South Savo was selected because woody biomass accounts for over half of the renewable energy supply in Finland (around 77% in 2019) (UNECE & FAO, 2017), and the majority of wood energy is sourced from indirect sources. For example, around 45% of energy is generated from black liquor sourced from the pulp and paper industries, representing a good example of the cascading uses of wood. South Savo was selected as the testing region because it is the most forested region of Finland, with forest land covering 85% of the land area[2].
- At a company level, BaySF was selected because it covers one third of Bavaria's forest area and 11% of Bavaria's total area, making it the largest forest enterprise in Germany[3]. Additionally, with around

[2] Luke Finland, Forest growth rate decelerated – volume of growing stock increased <https://www.luke.fi/en/news/forest-growth-rate-decelerated-volume-of-growing-stock-increased> [Accessed February 2024]

[3] Eustafor <https://eustafor.eu/members/bayerische-staatsforsten-aor/> [Accessed February 2024]

2,600 staff members the required data was readily available, unlike some private forests whose forestry owners are less likely to have the time and resources for data collection.

The indicator was intended to be tested in the region of Wallonia, in Belgium, because it has a relatively low production of renewable energy derived from woody biomass[4] and was impacted by Russia's invasion of Ukraine, as Belgium was a key importer of wood pellets from Russia. Given its share of renewable energy by 2030 is expected to be significantly below the EU average, it would have served as an interesting comparison to Bavaria, Germany, which produces high levels of woody biomass used for energy. However, due to a lack of forestry data for Belgium, the indicator boundary was changed to South Savo in Finland. Despite efforts to access data through the Belgium Open Data Initiative[5] (a government-led initiative to make public information accessible and usable) attempts to obtain relevant data from the three regional governments (Brussels, Wallonia and Flanders) were unsuccessful. More information can be found in the Deviation Log in Appendix 5.1.

The indicator was also originally due to be tested in two companies, however the boundary was reduced to one company due to challenges in collecting data. Company data on wood harvesting and sales is not made publicly available, and is not collected by key European organisations such as EUSTAFOR (European State Forest Association) and CEPF (Confederation of European Forest Owners), which represent all private and public forestry owners in Europe.

Material flow analysis

The methodology used to measure this indicator was a material flow analysis. This consisted of collecting data through a combination of desk-based research and stakeholder engagement with government agencies, federal statistical offices and industry bodies. Once data was collected, it was analysed to quantify the volume of wood types harvested and extracted from forests (i.e. roundwood, industry wood, energy wood and unused dead wood). The volume of wood sold for energy was then identified and its proportion relative to the total volume of forestry by-products was calculated using a straightforward MS Excel formula.

This method was selected because it not only measures the volume of wood going to energy generation, as per the indicator aim, but also captures the amount of wood used for other purposes such as fibreboards, enabling the identification of opportunities for increasing resource efficiency in the forestry industry.

2.1.2 Data collection method

The following datapoints were required to calculate the share of local forestry by-products going to energy generation:

- Total wood going to energy generation (m^3).
    - Energy wood.
    - Fuelwood/firewood.
- Total forestry by-products (m^3).
    - Energy wood.
    - Fuelwood/firewood.
    - Industry wood.
    - Unused wood (left on forest floor).

This data was collected through a combination of desk-based research and stakeholder engagement, and datasets were downloaded as three individual MS Excel spreadsheets from the sources outlined in Table 3.

[4] European Environment Agency, Share of energy consumption from renewable sources in Europe <https://www.eea.europa.eu/en/analysis/indicators/share-of-energy-consumption-from> [Accessed February 2024]

[5] Belgian Government <https://data.gov.be/en> [Accessed February 2024]

Table 3: List of data sources

#	Source	Data collected	Reliability*	Availability**
1	Bavarian State Institute for Forestry (Bayerische Landesanstalt Fur Wald Und Forstwirtschaft)[6]	Desk-based research: Data on the energy wood market for the region of Bavaria from 2006 to 2021 (page 18)	Medium	Medium
2	Bavarian State Forest Enterprise (BaySF)[7]	Stakeholder engagement: Company data not readily available, however data was provided through a contact of the team who is on the board of BaySF and was able to contact the sawmills to provide data on total felling and forestry sales for the entity.	Medium	Low
3	LUKE (Natural Resources Institute Finland) https://www.luke.fi/en/statistics	Desk-based research Data on forest statistics on wood consumption per region from 1980s-2022[8] Stakeholder engagement with LUKE's general enquiry to sense-check data.	High	High

* ***Low*** **=** *Some data was missing and incomplete, which may lead to inaccurate conclusions*, ***Medium*** **=** *The data was complete but may lack accuracy and quality,* ***High*** **=** *The data was complete, accurate and of high quality.*

****** ***Low*** **=** *The data was not already collected or readily available and was difficult to collect.* ***Medium*** **=** *The data was already collected but was not publicly available, OR the data was not already collected but was easy to collect,* ***High*** **=** *The data was readily available and was accessed easily.*

The three spreadsheets were consolidated into a single master spreadsheet (Appendix 5.3) where calculations were performed to estimate the indicator. Historic data was available from 2010 onwards for South Savo and Bavaria, and 2014 onwards for BaySF, so it was decided to monitor the indicator from those years onwards to identify trends in the data.

Stakeholder engagement exercise

Desk-based research found a lack of available data at a company level, so stakeholder engagement was carried out within the forestry industry and with a representative from the BaySF. An email was sent to a board member of the BaySF seeking assistance in acquiring the data, and an example of the email can be found in Appendix 5.1. Following an initial discussion to explain the project and data required, the contact facilitated the collection of data. The Excel spreadsheet containing the collected data can be found in Appendix 5.3 under the sheet labelled "BaySF raw data".

This stakeholder engagement exercise took place at the end of January 2024, with the required data returned to within one week. Further clarification emails were exchanged over the month of February, which were used to form certain assumptions. More details on these clarifications are provided in Section 2.1.3 and 2.1.5 .

[6] LWF, Untersuchung des Energieholzmarktes in Bayern hinsichtlich Aufkommen und Verbrauch <https://www.lwf.bayern.de/mam/cms04/service/dateien/energieholzmarktbericht_2020.pdf> [Accessed February 2024]

[7] Bayerische Staatsforsten <https://www.baysf.de/de.html> [Accessed February 2024]

[8] Wood consumption by Year, Region and Category of use. PxWeb <https://eustafor.eu/members/bayerische-staatsforsten-aor/.fi> [Accessed February 2024]

Data was also supplemented with background information on wood energy and forestry management from the sources outlined in Table 4.

Table 4: List of other sources used

#	Source	Data collected	Reliability*	Availability**
1	Joint Wood Energy Enquiry (JWEE)	Desk-based research: Collects national data on wood energy sources and volumes in EU Member States through the JWEE questionnaire. Stakeholder engagement: Received confirmation that the data is only available at a national level, therefore data was used to sense-check subnational level findings.	High	High
2	EUSTAFOR: Represent all publicly-owned forests in the EU	Desk-based research: Data not readily available. Stakeholder engagement: Contacted the Communications & Policy Officer who forwarded the data request to members. Members were not able to support the project.	N/A	Low
3	CEPF: Represent all private forests in the EU	Desk-based research: Data not readily available. Stakeholder engagement: Contacted the Office Manager who transferred the request to a relevant point of contact, who was not able to help in providing data.	N/A	Low

2.1.3 Calculations

The following calculations were used to assess the indicator and calculate the share of forestry by-products utilised for energy.

BaySF data

Step 1: Converting percentages into numbers

- Original data on round wood, industry wood, energy wood and unused wood consumption was provided as percentages of the total wood sales volume.
- Percentages were converted into numerical values to facilitate analysis using the formula = *(Total volume sold)*(%).*

Step 2: Calculating the amount of wood left on the forest floor

- The original felling data records how each year roughly 13% of wood felled is not sawable (NH).
- Through engaging with stakeholders, it was understood that some of this is left on the forest floor, but a large portion is chopped and used as energy wood.
- To determine the proportion of unused wood to include as a by-product (because it eventually decomposes releasing CO_2), the total wood sold was deducted from the total wood felled using the formula = *(Total wood felled)-(Total wood sold).*

Step 3: Calculating the total volume of energy wood

- BaySF data recorded firewood and energy wood data separately, therefore these figures were combined using the MS Excel formula = *SUM()* to obtain the total energy wood consumption each year to use in the final calculation.
- South Savo data recorded energy generation from roundwood and wood residues and by-products separately, so these figures were combined using the same formula to calculate the total wood going to energy generation.

Step 4: Calculating the total volume of by-products

- Energy wood, industry wood and unused wood were combined using = *SUM()* to obtain the total volume of by-products to use in the final calculation.

Step 5: Calculating the share of by-products going to energy generation

- The following formula was applied in MS Excel: = *(Total energy wood)/(Total by-products)*100.*

2.1.4 Timeline

Table 7 below shows the Gantt chart highlighting the testing timeline.

Table 5: Gantt chart of the indicator timeline

w/c	01/01	08/01	15/01	22/01	29/01	05/02	12/02	19/02	26/02	04/03	11/03	18/03	25/03
Define system boundary													
Desk-based research													
Stakeholder engagement													
Develop methodology													
Case study writing													
Review period													
Key deliverables													

2.1.5 Data gaps and mitigation

Table 8 summarises the data gaps identified throughout the testing phase and the efforts made to mitigate those gaps to obtain meaningful insights.

Table 6. Overview of identified data gaps, limitations and mitigation efforts

	Description of data gap	Mitigation efforts	Level of confidence
1	Forestry owners may not accurately record all by-products created from harvesting wood. For example, stakeholder engagement indicated forestry owners occasionally offer by-products in exchange for payment for certain goods and services, such as laying roads, and this exchange would not be reflected in the data.	At a company level, the indicator was tested on a state-owned forest (BaySF) rather than privately owned forest as data is more transparent.	High
2	Data submitted by a region or company may not be representative of other regions or forests across the EU.	BaySF was chosen to represent forestry data at a company level as it is a state-owned forest covering an area over 800,000 ha and is the largest forest enterprise in Germany[9]. This is more representative than selecting a privately owned forest to test the indicator on, given over half of privately owned holdings in Germany are less than 20ha (BMEL, 2015).	High
3	Data provided on roundwood felling and sales did not specify what quantity remained as sawn logs, nor the quantity used as fuel or processed to make boards, paper, or energy wood for example.	Engaged with relevant stakeholders to better understand the uses of roundwood once harvested and removed: • A general enquiry was sent to Finland's statistical database, who responded stating most logs are used in sawmills, and wood harvested for energy almost always stays as energy wood because it has no added value. Some timber harvested for industry however, such as pulpwood, can end up going to energy generation if left to rot on the side of the road. This data is often not recorded and therefore is a limitation to the work. • Correspondence with BaySF confirmed that roughly 30% of roundwood goes to fibreboards or pulpwood, and 70% remains as sawn timber. This assumption was used for South Savo data, which did not specify the proportion of roundwood that remains as sawn timber. • For Bavarian and BaySF data, roundwood volumes were recorded separately to industry wood volumes. Therefore, while it was not possible to confirm the exact use of the roundwood, the same assumption was made for both datasets that it was sawn logs,	Medium

[9] Eustafor <https://eustafor.eu/members/bayerische-staatsforsten-aor/> [Accessed February 2024]

	Description of data gap	Mitigation efforts	Level of confidence
		and therefore excluded as a by-product in calculations.	

2.1.6 Quality review of analysis

To ensure robust and high-quality results, the following data validation and quality control procedures were followed:

- Prior to work beginning, the Project Director reviewed the proposed research methodology and ensured that the data collection plan was fit for purpose. Once the research team had addressed any comments from the review process, they proceeded to the data collection phase.
- The Project Manager reviewed the work done.
- The Quality Assurance Manager held responsibility for the quality of the final case study output. The Project Manager assisted the Quality Assurance Manager in judging the quality of the output and suggesting ways to improve.

2.2 KEY ANALYSIS RESULTS

2.2.1 Analysis

The share of by-products going to energy generation is shown in Table 7.

Table 7: Share of by-products going to energy generation in South Savo, Bavaria and BaySF

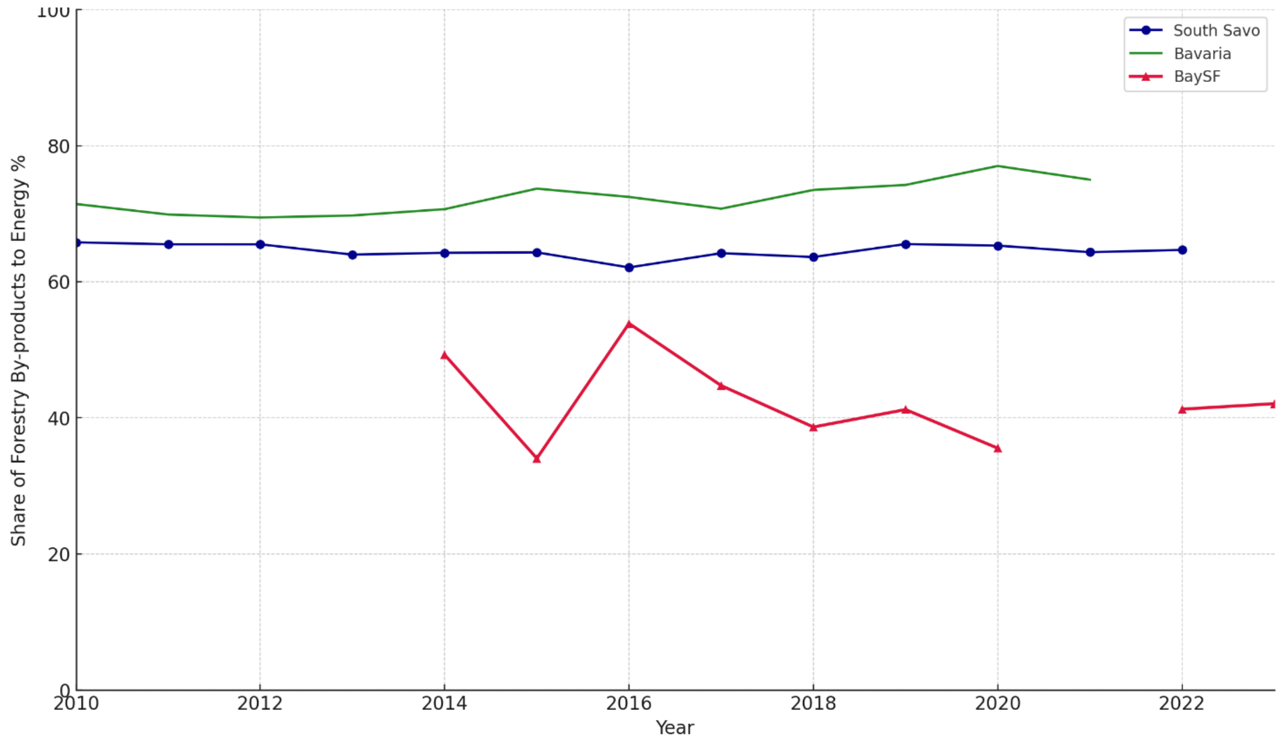
Year	South Savo	Bavaria	BaySF
2010	66%	71%	N/A
2011	66%	70%	N/A
2012	65%	69%	N/A
2013	64%	70%	N/A
2014	64%	71%	49%
2015	64%	74%	34%
2016	62%	72%	54%
2017	64%	71%	45%
2018	64%	73%	39%
2019	66%	74%	41%
2020	65%	77%	36%
2021	64%	75%	N/A
2022	65%	N/A	41%
2023	N/A	N/A	42%

Figure 2 below visualises the results from Table 7, depicting how Bavaria has the highest share of local forestry by-products going to energy generation. It can therefore be concluded that Bavaria does not use wood resources as efficiently as South Savo and BaySF, sourcing more wood energy directly from the forest rather than from by-products and residues. The graph also depicts how market forces and factors influencing the price of wood products and by-products (i.e. fibreboards or energy wood) have a greater impact on the share of wood going to energy generation at a company level than a regional level.

BaySF sends the lowest share of wood to energy, which correlates to the explanation provided by BaySF stakeholders that state-owned forests tend to send less wood to energy than small private holdings, which make up the majority of forest land in Bavaria. The higher consumption of wood energy in South Savo is also reportedly explained by non-industrial private forest owners deciding to sell energy wood (Sinikka Mynttinen, 2014).

Please note, there was an anomaly in the data for BaySF for the year 2021 therefore this was excluded from the results.

Figure 2: Comparative analysis of the share of by-products going to energy generation



2.2.2 Limitations

There are a number of limitations to this work due to uncertainties associated with the data:

- **Definition of roundwood**. The data provided by South Savo, Bavaria, and BaySF separate the volume of wood harvested into the following categories: 'roundwood', 'industry wood', 'energy wood' and 'unused wood'. The definition for roundwood is "*all wood obtained from removals… It is an aggregate comprising fuelwood and industrial roundwood*"[10]. While this definition indicates that roundwood includes sawn logs as well as by-products (i.e. industry wood and fuelwood), it was not possible to ascertain from the data what proportion of roundwood remains in its primary form as sawn logs, and what proportion is processed into a by-product (i.e. fibreboards or wood chips etc.). Therefore, where the data separated 'industry wood' and 'energy wood', the assumption made was that roundwood represented sawn logs and was excluded as a by-product. This limitation affects the accuracy of the analysis.
- **Differences in wood allocation**. Through engaging with BaySF stakeholders, it was learned that they send less wood to energy than private forestry owners in Germany, and that the smaller the forest, the more wood goes to energy and the less dead wood stays in the forest. The team sent a

[10] European Commission, Supporting policy with scientific evidence <https://knowledge4policy.ec.europa.eu/glossary-item/roundwood_en> [Accessed February 2024]

data request to CEPF, the association of private forest owners, support for the project was unavailable. In future, private forest data should be analysed for a more robust result.

- **Local distribution of forestry by-products**. The indicator is the 'share of local forestry by-products to energy', however it was not possible to collect data on whether the forestry by-products are distributed and used 'locally'. Time constraints prevented the search for this data. It is expected that further stakeholder engagement would be needed with the sawmills to obtain this information.
- **Lack of data on unused wood**. It was not possible to obtain data on the amount of wood unused and left on the forest floor for South Savo, as this data is seemingly not recorded in Finland. This limitation restricts our understanding of the complete wood utilisation process in the region.

2.2.3 Performance

The indicator received a lower score in the RACER evaluation following testing compared to the original assessment as shown in Table 8. Details on the scoring are available in Appendix 5.1. The updated scoring was based on the following considerations:

- **Relevance**: The indicator is closely linked to the objective of measuring circularity in the bioeconomy because it is beneficial to monitor the share of forestry by-products going to energy generation compared to the share of products and by-products going to construction or fibre-based products for example to assess how efficiently wood as a resource is being used, and how long carbon is being sequestered in the primary product before it is released into the atmosphere.
- **Acceptability**: Data on this indicator is collected and used by policymakers and industry and therefore considered acceptable.
- **Credibility**: The data lacks clarity on the uses of harvested wood, for example whether logs are used for construction or residentially as fuel wood, and therefore is only partially transparent, trustworthy and easy to interpret.
- **Ease**: The data is accessible and easy to monitor only for certain regions and companies, depending on how developed their technology and methods for data collection are, and whether they have the resources to collect the required data. For example, the data is less accessible for private forests who have fewer staff and are not required to submit harvesting data.
- **Robustness**: Due to the limitations described in Section 2.2.2 the results of the indicator lack robustness.

Table 8. RACER evaluation (Scored 1-3 with 1 being poor and 3 being good)

Stage of project	RACER criterion					Score
	Relevance	Acceptability	Credibility	Ease	Robustness	
Task 4 (original RACER assessment)	3	3	3	3	2	14
After Task 5 (following testing)	3	3	2	2	1	11

2.3 CHALLENGES AND LESSONS LEARNED

There were challenges during the testing process, in particular obtaining granular data, which were addressed throughout the process and mitigations were implemented where possible (see Table 6). The key challenges are outlined below:

2.3.1 Challenges

- Collecting company-level data:
    - Initially the goal was to gather data from up to three companies to allow for better comparison on the indicator however this was not achievable.
    - Despite reaching out to industry stakeholders and CEPF, the umbrella association representing all forest owners in Europe, sending the data request to European members, no positive response was received.
    - Data at a company level was only obtained for BaySF, facilitated by having a contact on the company board.
- Defining forestry terms and wood flows:
    - There are no standardised definitions around roundwood, energy wood and industry wood, and data does not clearly specify what is categorised as roundwood, energy wood etc. Where this was the case, assumptions had to be made based on engagement with stakeholders in the industry, by estimating the proportion of roundwood that remains as sawn logs, the proportion used in industry and the proportion going to energy generation or left unused on the forest floor.
- Most datasets do not specify whether the energy wood has been sourced directly (i.e. straight from the forest) or indirectly (i.e. created from waste streams from wood processing activities).

2.3.2 Lessons learned

- A longer timeline would be required for the data collection phase, to gain a larger dataset and clarify certain points with relevant stakeholders to minimise assumptions.
- Greater engagement with CEPF would be required to understand why private forestry owners in Europe were unwilling or unable to provide data for the indicator.

2.4 CONCLUSIONS AND RECOMMENDATIONS

It is recommended that this indicator is considered for further development, with minor work required to facilitate its progress.

This indicator is suitable for further development across EU Member States as it has shown to be relevant to the CE and bioeconomy sector by indicating how efficiently wood resources are used. While the data is not readily available for individual forests and certain EU regions, the indicator is widely accepted by stakeholders and the required data is likely to be collected by most forests even if it is not publicly available. Clearer definitions and reporting guidelines around by-product categories, and whether energy wood is sourced directly or indirectly would enable the indicator to be more robust and replicable across EU Member States.

As stated in the introduction, the aim of this indicator is not to see an increase in the share of forestry by-products going to energy generation, but to ensure that wood going to energy generation is being used as a last resort. Therefore, it is recommended that this indicator measures biomass utilisation efficiency to capture the cascading use of wood, and how long the material is kept in use before generating energy (Christopher vom Berg, 2023). This would mean monitoring the source of wood energy, as Finland does to an extent and is shown in the South Savo data. The indicator should aim to see a decrease in wood energy sourced directly (i.e. from the forest) and an increase in wood used as sawn logs, before it is incinerated to produce energy only after following the cascading use depicted in Figure 1. This means using the indicator in conjunction with other indicators, such as the share of forestry by-products going to fibreboards and pulpwood for example, to obtain a full picture of how efficiently forestry resources are being used.

Additionally, the analysis showed there is a positive correlation between an increase in wood going to energy generation and the introduction of renewable energy policies in the EU such as the RED. These policies have affected woodworking value chains, as wood residues are increasingly being used for energy rather than co-products such as panels or boards creating a squeeze in supply and an increase in raw material costs (UNECE & FAO, 2021). This is important because from a CE and resource efficiency perspective, wood's structural integrity should be maintained for as long as possible before it is transformed into energy. Therefore, it is recommended that legislation is developed to ensure energy wood is used in accordance with the cascade (Figure 1), as was proposed by the European parliament in 2023 under RED III to cap the use of primary woody mass and deem it unsustainable[11].

While regional level data was readily available for some EU Member States, collecting data at a company level posed challenges, with only BaySF data obtainable due to existing contacts. It is therefore recommended that companies and private forestry owners are better supported in data collection through standardising definitions and providing more detailed guidance around reporting requirements. However, we suggest establishing a threshold so that only large companies and forestry owners are required to collect data in order to avoid additional burden on small companies and private forestry owners. This is because it was not deemed realistic to ask small companies and private forestry owner to efficiently collect data to measure this indicator.

Following the testing of this indicator, it was found that its original name 'Share of local forestry and agricultural waste by-products going to energy generation' was not entirely fit for purpose and therefore a variation was suggested. Indeed, to focus on one industry to allow for a more accurate output and measure of circularity it was decided to remove the 'agricultural' aspect to this indicator. Also, the term 'waste' was removed from the name after consultation with forestry industry stakeholders revealed that all by-products have a use and are not considered waste. Therefore, the updated name for this indicator was set for 'Share of local forestry by-products going to energy generation'.

Finally, this indicator would complement the new EU monitoring framework by highlighting the role of sustainable forestry in the EU's energy mix and monitoring efforts to utilise all parts of harvested materials in the most efficient way possible. It would also encourage better data collection on the uses of forestry by-products, which could facilitate more informed policymaking, and help policymakers identify best practice, as well as regions and companies that require more support to utilise biomass in a more efficient and circular manner.

[11] ENDS Europe, RED: Blocking minority in Council against curbs on primary Woody biomass <https://www.endseurope.com/article/1815453/red-blocking-minority-council-against-curbs-primary-woody-biomass> [Accessed February 2024]

Table 9: Summary of recommendations for indicator B2

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
Legislation	Introduce legislation to ensure wood energy is sourced solely from by-products, and not in conjunction with roundwood from the forest, to ensure wood is used according to the cascading uses of wood in Figure 1.	Credibility and Robustness	Medium (1.5-5 years)	Responsible: EC Accountable: EC and National EU governments Consulted: relevant industry bodies and forestry owners. Informed: EU regions and relevant companies and public.
Development of data collection	Regions and companies should aim to record energy wood sourced directly and indirectly, as demonstrated by South Savo data.	Ease and Robustness	Short (0.5-1.5 years)	Responsible: EC Accountable: EC and National EU governments. Consulted: relevant industry bodies and forestry owners. Informed: relevant companies and public.
Development of guidance	Better guidance around definitions and data collection should be provided to support data collection for large companies and private forestry owners.	Credibility, Ease and Robustness	Short (0.5-1.5 years)	Responsible: EC Accountable: EU state members and regional governments. Consulted: relevant industry bodies and forestry owners. Informed: relevant companies and public.
Indicator development	Monitor indicator alongside a more detailed set of indicators including share of forestry by-products to sawn logs, pulpwood, and the share remaining on forest floor, to enable better monitoring of biomass utilisation efficiency.	Credibility	Medium (1.5-5 years)	Responsible: EC Accountable: EC Consulted: relevant industry bodies and forestry owners.

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
				Informed: National governments, relevant companies and public.
Integrate data reporting requirements into certification schemes	Integrating data reporting requirements into certification schemes or compliance regulations for sustainable forestry and bioenergy production could incentivise accurate and timely data collection and reporting.	Credibility and Ease	Short (0.5-1.5 years)	Responsible: EC Accountable: EU state members and regional governments. Consulted: relevant industry bodies and forestry owners. Informed: relevant companies and public.

3. INDICATOR 2: THE SHARE OF ORGANIC FERTILISER USED AS A PROPORTION OF OVERALL FERTILISER USE IN AGRICULTURAL PRACTICES

This indicator measures the share of organic fertiliser used in agricultural practices at a regional level in the EU. The definition of organic fertiliser used for this indicator is based on the European Environment Agency's definition, where organic fertilisers are:

> *"Materials of animal origin used to maintain or improve nutrition and the physical and chemical properties and biological activities of soils, either separately or together, they may include manure, digestive tract content, compost and digestion resides"*[12].

Therefore, the indicator excludes organic plant material such as cover crops or green manure, although these practices are being used more frequently as a substitute for fertilisers and pesticides[13].

The indicator was initially intended to be measured at a company level as well as a regional level, however the decision was made to change the boundary to regional only because data from individual farms was not publicly accessible, and regional data was considered sufficiently representative since it is made up of individual farm statistics. Additionally, assessing the indicator at a company level would not produce as meaningful results as the outcome is predictable. For example, it is expected an organic farm would only use organic fertiliser, given strict EU rules prohibiting the use of synthetic fertilisers, and a non-organic farm would mainly use synthetic fertilisers.

The aim of the indicator is for the share of organic fertiliser used to increase, without the overall use of fertiliser increasing. This is because increase in the share of organic fertiliser used would demonstrate that biological materials are being recycled back into the bioeconomy more efficiently and contributing to the long-term health of soils[14]. Organic fertilisers enhance soil structure, fertility, and biodiversity, creating soils that are more resilient to climate change. They also reduce the need for chemical inputs, such as synthetic fertilisers, which use more energy and water to produce (Wentworth, 2014).

There are many benefits to monitoring this indicator, for example:

- Enabling the EU to track the environmental impact of the agricultural sector. An increase in the use of organic fertiliser would lower greenhouse gas emissions (Zijian He a, 2023), reduce chemical runoff into water bodies and decrease soil degradation.
- Reflecting the success of waste management practices in agriculture. Using organic waste, such as manure, helps to close the loop in nutrient and organic matter cycles[15].
- Reducing the need for, and environmental burden of the production of, synthetic fertilisers. This reduces costs for farmers and provides an additional revenue stream for producers of compost or manure.
- Supporting rural economies and helping to develop local circular economies, strengthening the social and economic resilience of the EU.
- Helping to monitor the effectiveness of other EU policies, such as the EU Green Deal and the Farm to Fork Strategy16, which has set a target of at least 25% of the EU's agricultural land to be under organic farming by 2030.

[12] European Environment Agency, Organic Fertiliser, 2002 < https://www.eea.europa.eu/help/glossary/eea-glossary/organic-fertiliser> [Accessed February 2024]

[13] UK Government, Use cover crops or green manure <https://defrafarming.blog.gov.uk/sustainable-farming-incentive-pilot-guidance-use-cover-crops-or-green-manure/> [Accessed February 2024]

[14] IFOAM Organics Europe, Organic benefits for climate and biodiversity <https://www.organicseurope.bio/library/organic-benefits-for-climate-and-biodiversity/> [Accessed February 2024]

[15] Ellen Macarthur Foundation, Closing the Nutrient Loop <https://www.ellenmacarthurfoundation.org/circular-examples/closing-the-nutrient-loop> [Accessed February 2024]

[16] European Commission, Organic Action plan <https://agriculture.ec.europa.eu/farming/organic-farming/organic-action-plan_en> [Accessed February 2024]

3.1 KEY METHODOLOGY

3.1.1 Testing method

This section outlines the method used to measure the specified indicator at a regional level, focusing on Brandenburg and Bavaria in Germany, and Opolskie in Poland.

Figure 3 - Map of Germany highlighting the regions of Brandenburg and Bavaria[17]

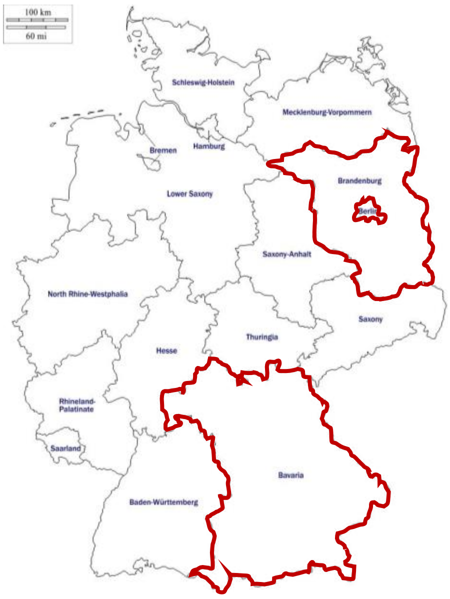


Figure 4 - Map of Poland highlighting the region of Opolskie[18]

Rationale for regional selection

This indicator was measured at a regional level, limited to the regions of Brandenburg and Bavaria in Germany and Opolskie in Poland.

Brandenburg and Bavaria were selected due to Germany's publication of their national strategy in early 2024, which includes a target for 30% of food and farming to be organic by 2030 (Federal Ministry of Food and Agriculture - Germany, 2024). According to IFOAM (International Federation of Organic Agriculture Movements) Organics (2022), which is the worldwide umbrella organisation for organic food and farming, only 9.7% of Germany's agricultural area is currently farmed organically, indicating that the use of organic fertiliser

[17] Germany Map 360 <https://germanymap360.com/germany-blank-map> [Accessed March 2024]

[18] Ursula Markowska -Przybyła, Research Gate, <https://www.researchgate.net/figure/Map-of-the-regions-of-Poland-as-in-the-text-the-Polish-names-of-the-regions-are-used_fig1_307466358> [Accessed March 2024]

in Germany needs to significantly increase over the next six years if Germany is to meet the target. The same source evaluated Common Agricultural Policy (CAP) Strategic Plans and found that the current budget for organic farming will only enable Germany to reach 14% organic by 2030, making it important to monitor progress through this indicator.

The region of Opolskie in Poland was selected because Poland has a large agricultural sector, yet only 3.4% of Poland's agricultural land is farmed organically (based on 2020 data). Poland has set a target to be 7.0% organic by 2030, but IFOAM Organics evaluates this target is insufficient to support the EU's overall target of 25% organic by 2030 (IFOAM Organics, 2022). Opolskie was selected due to it having the highest synthetic fertiliser consumption from all Polish regions (Piwowar, 2021).

Initially the indicator was planned to be tested in the Steiermark region of Austria, which has the highest levels of organic farming in the EU, with 26.5% of its agricultural area being organically farmed in 2021[19]. The aim was to provide a contrast between regions. However the region was changed to Bavaria after challenges finding statistics on fertiliser consumption in Austria through desktop research and engaging with stakeholders listed in Appendix 5.6.

Data limitations

Historic data on fertiliser consumption was sporadic, and generally only available at a national or sub-national level every few years because agricultural censuses being conducted intermittently, or in Poland's case every ten years. Attempts were made to calculate the share of organic fertiliser used using proxy data for the missing years, but the figures deviated significantly from the reported data. Therefore it was decided to exclude these years and only monitor the indicator for years with available data, supplemented by proxy data where necessary, for consistency and accuracy. These years were 2013, 2016 and 2020 for Opolskie, and 2016 and 2020 for Brandenburg and Bavaria.

Material flow analysis

The methodology used to measure this indicator involved conducting a material flow analysis. This consisted of collecting data on the quantity of organic fertiliser applied in tonnes per hectare (t/ha) in the chosen region and the total quantity of synthetic fertiliser applied (t/ha). Where data on organic or synthetic fertiliser was unavailable, proxy data was used by determining a national average and applying it to the utilised agricultural area for that region. Further details on the data collection process is outlined in Section 3.1.2.

3.1.2 Data collection method

The following datapoints were required to calculate the share of organic fertiliser used per region:

- Total use of Synthetic fertilisers (tonnes).
- Total use of organic fertiliser (tonnes).
- Total area of agricultural land (hectares).

The data was collected through desk-based research, and datasets were downloaded as individual MS Excel spreadsheets or PDFs if in report format from the sources outlined in Table 10.

[19] Eurostat, Developments in Organic Farming <https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Developments_in_organic_farming&oldid=614575> [Accessed February 2024]

Table 10: Summary of data collection sources

Datapoint	Bavaria	Brandenburg	Opolskie
Use of Synthetic fertilisers	• Destatis, Specialist Series 3, Series 2.2.2[20] [accessed 28/01/24] • CEIC Data (a global database), Fertiliser Consumption per hectare[21] [accessed 22/02/04]	• Destatis, Specialist Series 3, Series 2.2.2 [accessed 28/01/24] • CEIC, Fertiliser Consumption per hectare [accessed 22/02/04]	• The Central Statistical Office of Poland (GUS)[22] [accessed 16/02/24] • Eurostat database[23] [accessed 13/02/2024)
Use of organic fertilisers	• Destatis, Specialist Series 3, Series 2.2.2 [accessed 28/01/24]	• Destatis, Specialist Series 3, Series 2.2.2 [accessed 28/01/24]	• Management of Natural Fertilisers in Poland[24] [accessed 24/02/24] • Spatial diversity of Organic Farming in Poland[25] [accessed 24/02/24] • General Agricultural Census 2010 and 2020[26] [accessed 16/02/24]
Area of agricultural land	• Destatis database - Agricultural Holdings and Utilised Agricultural Area[27] [accessed 12/02/24]	• Destatis database – Agricultural Holdings and Utilised Agricultural Area [accessed 12/02/24] • Eurostat database[28] [accessed 24/02/24]	• Eurostat database[29] [accessed 24/02/24]

Data from the data collection sources was combined into one master spreadsheet (Appendix 5.5), using proxy data added in italics where original data was unavailable.

Process for calculating proxy data

[20] Destatis <https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Produktionsmethoden/Publikationen/Downloads-Produktionsmethoden/wirtschaftsduenger-2030222209004.html> [Accessed February 2024]

[21] CEIC, Germany DE: Fertilizer Consumpter per Hectare of Arable Land <https://www.ceicdata.com/en/germany/agricultural-production-and-consumption/de-fertilizer-consumption-per-hectare-of-arable-land> [Accessed February 2024]

[22] Polish Statistical Office <https://stat.gov.pl/obszary-tematyczne/rolnictwo-lesnictwo/psr-2020/powszechny-spis-rolny-2020-raport-z-wynikow,4,1.html> [Accessed March 2024]

[23] Eurostat, Consumption of Inorganic Fertilizers <https://ec.europa.eu/eurostat/databrowser/view/aei_fm_usefert/default/table?lang=en&category=agr.aei.aei_nut> [Accessed February 2024]

[24] Jerzy Kopiński, Management of Natural Fertilizers in Poland <https://www.researchgate.net/publication/342430276_MANAGEMENT_OF_NATURAL_FERTILIZERS_IN_POLAND> [Accessed February 2024]

[25] Małgorzata Kobylińska, Spatial Diversity of Organic Farming in Poland <//www.mdpi.com/2071-1050/13/16/9335#table_body_display_sustainability-13-09335-t001> [Accessed February 2024]

[26] Polish Statistical Offices <https://stat.gov.pl/obszary-tematyczne/rolnictwo-lesnictwo/psr-2020/powszechny-spis-rolny-2020-raport-z-wynikow,4,1.html> [Accessed February 2024]

[27] Destatis <https://www.destatis.de/EN/Themes/Economic-Sectors-Enterprises/Agriculture-Forestry-Fisheries/Agricultural-Holdings/Tables/agricultural-holdings-and-utilised-agricultural-areaby-size-of-the-utilised-agricultural-area.html> [Accessed February 2024]

[28] Eurostat <https://doi.org/10.2908/EF_M_FARMLEG> [Accessed February 2024]

[29] Eurostat <https://doi.org/10.2908/EF_M_FARMLEG> [Accessed February 2024]

- Regional data on the use of Synthetic fertilisers for Bavaria and Brandenburg was unavailable, so data was taken from CEIC on the annual average fertiliser use in Germany and from Destatis on the Utilised Agricultural Area (UAA) to estimate the average amount applied. The following formula was used: *Total use of Synthetic fertiliser (t) = Synthetic fertiliser application (t/ha) x UAA (ha)*
- Data on organic fertiliser use was unavailable for Opolskie, so an average was calculated using data from the Management of Natural Fertilisers in Poland on annual application rates, and the Organic Agricultural Area (OAA) from the Polish Agricultural Census. The following formula was used: *Total use of organic fertiliser (t) = organic fertiliser application (t/ha) x OAA*

The data collection process and desk-based research exercise took place between the start of January 2024 to mid-February 2024.

3.1.3 Calculations

The following steps were taken to calculate the share of organic fertiliser used for each region.

Step 1: Converting units into tonnes

Given the metric for the indicator is tonnes per hectare, data for liquid manure and slurry was recorded in cubic metres and needed to be converted into tonnes.

The following conversion methodology was employed, estimating a density of 1,200 kg/m3 for liquid fertiliser and slurry[30]: *Mass (tonnes) = Volume (m3) x 1,200 (density, kg/m^3) / 1,000.*

Step 2: Calculating total fertiliser use and total organic fertiliser use

Annual organic and total fertiliser consumption were added together using the MS Excel formula = SUM(), to calculate the total consumption:

- Total organic fertiliser consumption = *SUM (liquid fertiliser + solid manure).*
- Total fertiliser consumption = *SUM (total organic fertiliser + Synthetic fertiliser).*

Step 3: Calculating the fertiliser application rates per hectare

The amount of fertiliser applied varies based on the size of the agricultural area. Therefore, to be able to compare the share of fertiliser used in the three regions, the application rate per hectare was calculated using the following formulas:

- *Organic Fertiliser Application Rate (OFAR) = Total organic fertiliser / UAA.*
- *Total Fertiliser Application Rate (TFAR) = Total fertiliser used / UAA.*

Step 4: Final calculation

The results of the previous steps were used to calculate the share or organic fertiliser used for each region:

- *Share of organic fertiliser used = OFAR / TFAR x 100.*

These calculations are in Appendix 5.5 and Section 3.2 show the results.

[30] The Engineering ToolBox, Slurry Density <https://www.engineeringtoolbox.com/slurry-density-calculate-d_1188.html> [Accessed February 2024]

3.1.4 Timeline

Table 11: Gantt chart of the indicator timeline

w/c	01/01	08/01	15/01	22/01	29/01	05/02	12/02	19/02	26/02	04/03	11/03	18/03	25/03
Define system boundary													
Desk-based research													
Stakeholder engagement													
Develop methodology													
Case study writing													
Review period													
Key deliverables													

Table 11 shows a timeline of the different tasks completed during indicator development.

3.1.5 Data gaps and mitigation

Table 12 summarises the data gaps identified throughout the testing phase and the efforts made to mitigate those gaps to obtain meaningful insights. Green indicates a high level of confidence, amber a medium level and red a low level of confidence.

Table 12. Overview of identified data gaps, limitations and mitigation efforts

	Description of data gap	Mitigation efforts	Level of confidence
1	Data was unavailable at a regional level for many EU Member States.	• The indicator was chosen to be tested only in regions where at least some data was made publicly available.	High
2	Data on organic fertiliser consumption in Poland was unavailable at a regional level.	• Proxy data was found on average manure, liquid manure and slurry applied (t/ha) for the years 2018/2019 in Poland. This was used to calculate total organic fertiliser consumption for all years given an average could not be found for other years. This is a limitation of the work. • The use of proxies introduces the potential for inaccuracies in results as they are not perfect representations of the data.	Medium

	Description of data gap	Mitigation efforts	Level of confidence
3	Data on Synthetic fertiliser consumption in Germany was unavailable at a regional level.	• Proxy data was found on the average consumption per hectare for 2016 and 2020 for each region of Germany. This was used to calculate the total synthetic fertiliser consumption. • The use of proxies introduces the same risks as previously described.	Medium
4	Inconsistent data collection methodologies across Member States may affect the accuracy of organic fertiliser usage data as findings cannot be directly compared.	• Data gap would be mitigated through only selecting regions which use the same data collection methodology, or where known farm inspections take place, however methodologies were not readily available and time resources were limited for further investigation.	Medium
5	Informal or traditional farming practices may use organic fertiliser which may not be adequately captured in official data.	• Data gap would be mitigated through verifying data with local agricultural agencies and industry associations, however time resources were limited and stakeholders were unresponsive.	Medium
6	Data on fertiliser consumption is sporadically collected, mainly during agricultural censuses, which occur every few years or every 10 years.	The indicator was chosen to be tested only for the years where data was recorded from agricultural censuses or national statistic agencies to ensure it was as consistent and accurate as possible.	High

3.1.6 Quality review of analysis

To ensure robust and high-quality results, the following data validation and quality control procedures were followed:

- Prior to work beginning, the Project Director reviewed the proposed research methodology and ensured that the data collection plan was fit for purpose. Once the research team had addressed any comments from the review process, they proceeded to the data collection phase.
- The Project Manager reviewed the work done.
- The Quality Assurance Manager held responsibility for the quality of the final case study output. The Project Manager assisted the Quality Assurance Manager in judging the quality of the output and suggesting ways to improve.

3.2 KEY ANALYSIS RESULTS

3.2.1 Analysis

A breakdown of the analysis for Opolskie, Bavaria and Brandenburg can be seen in Table 13, Table 14 and Table 15 below.

Table 13: Share of organic fertiliser used in Opolskie

Year	UAA (ha)	OFAR (t/ha)	TFAR (t/ha)	Share of OF
2013	520,990	0.51	0.62	82%
2016	511,820	0.33	0.44	74%
2020	519,180	0.43	0.54	80%

Table 14: Share of organic fertiliser used in Bavaria

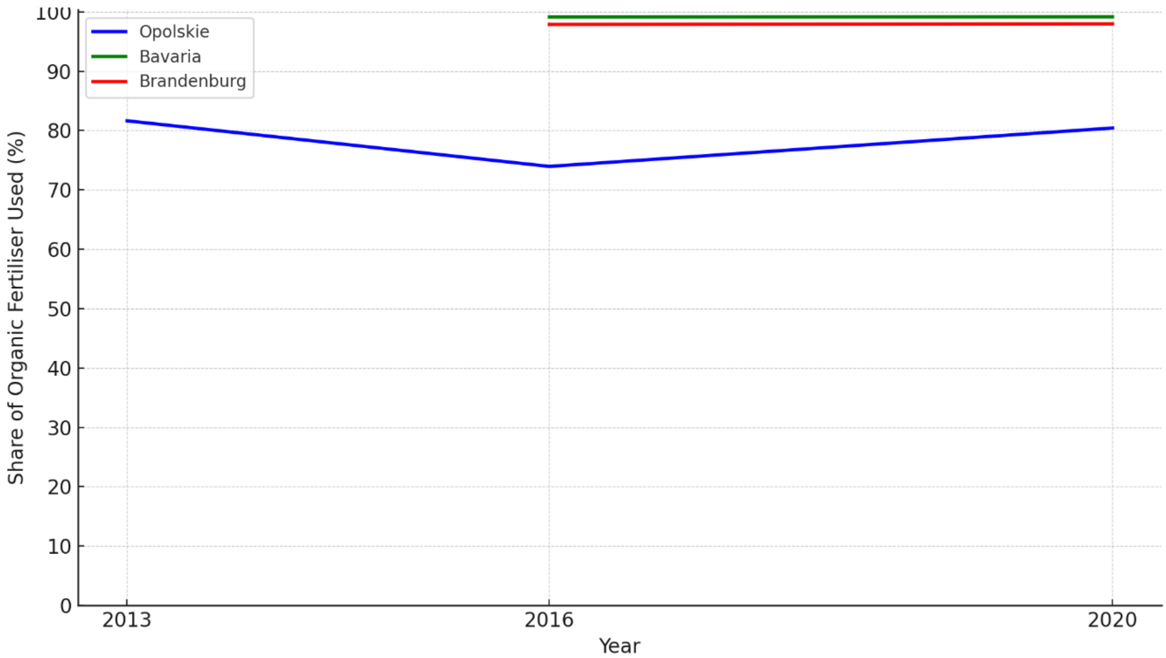
Year	UAA (ha)	OFAR (t/ha)	TFAR (t/ha)	Share of OF
2016	3,125,366	21.94	22.14	99%
2020	3,107,697	18.87	19.03	99%

Table 15: Share of organic fertiliser used in Brandenburg

Year	UAA (ha)	OFAR (t/ha)	TFAR (t/ha)	Share of OF
2016	1,315,469	9.02	9.22	98%
2020	1,305,800	7.86	8.02	98%

The results shown in Table 13 - Table 15 and depicted in Figure 6 indicate that all three regions use a high share of organic fertiliser, with Bavaria and Brandenburg's share ranging between 98-99% and Opolskie's between 74-82%. This is significantly higher than the expected result, given Germany's organic area is only 9.7% of agricultural land, and Poland's is 3.7% (IFOAM, 2022). The results are also not in line with Polish government statistics, which report that Opolskie consistently consumes the highest share of synthetic fertilisers out of all Polish regions (Ministry of Agriculture and Rural Development, 2015). The data conveys a flaw in the methodology used, caused by the decision to quantify fertiliser use based on weight. This introduced a bias in favour of organic fertilisers, which inherently possess a higher weight compared to Synthetic fertilisers. This is explained in more detail in Section 3.2.2.

Figure 5: Share of organic fertiliser used in three EU regions



3.2.2 Limitations

The main limitations and uncertainties associated with data are summarised below:

- A notable limitation in the methodology was calculating the share of organic fertiliser used based on the amount of fertiliser applied in tonnes per hectare. Organic fertilisers have a lower density of nutrients compared to Synthetic (synthetic) fertilisers; therefore they are applied at significantly higher rates to meet the same nutrient demand. Measuring by weight without accounting for the disparity has inflated the consumption rate of organic fertilisers. For example, our calculations suggest that organic fertilisers accounts for between 98-99% of fertiliser use in Germany, and 74-82% in Poland, when data shows only 9.4% of Germany and 3.4% of Poland's agricultural area is farmed organically (IFOAM Organics, 2022). Therefore, the methodology disproportionately reflects the use of organic fertilisers, and highlights a flaw in using volume-based metrics alone to assess the share of organic fertilisers.
- Another limitation to the work was the need to use proxy data, as organic fertiliser statistics were not available at a regional level in Poland, nor were Synthetic fertiliser statistics in Germany.
- Proxy data on fertiliser application rates were not tailored to the type of agricultural land, for example grassland or cropland. Given fertiliser application rates vary depending on the land type, this is a limitation of the work.
- Proxy data was calculated using the average application rate of fertiliser per hectare, multiplied by the area of organic or non-organic agricultural land. However, this method did not account for the fact that non-organic farmland may still apply certain quantities of organic fertiliser to the land alongside Synthetic fertiliser.
- Many agricultural practices are subject to seasonal variations. In using annual data this perhaps limits the ability to capture the nuances of fertiliser use throughout different planting and growing seasons.

3.2.3 Performance

The indicator's score in the RACER evaluation was slightly lower after testing than it was in the initial assessment as shown in Table 16. Details on the scoring are available in Appendix 5.1. Based on these factors:

- **Relevance**: Despite a flaw in the methodology used to measure the share of organic fertiliser used, the indicator remains a valuable measure of circularity in the bioeconomy. With a refined approach it could effectively track the efficiently biological resources and materials (i.e. organic waste) are being recycled back into the bioeconomy and contributing to the long-term health of soils.
- **Acceptability**: Data on fertiliser consumption is collected by some EU Member States through agricultural censuses, therefore this indicator is considered acceptable by most stakeholders.

- **Credibility**: The calculation for the indicator incorporated some proxy data. However this data was obtained from reliable resources and was easy to interpret.
- **Ease**: Ease of monitoring this data varied by region, influenced by technological and data collection capabilities.
- **Robustness**: Due to the limitations described in Section 3.2.2 the results of the indicator are not currently robust. Adopting an improved methodology is necessary to enhance its reliability.

Table 16: RACER Evaluation (Scored 1-3 with 1 being poor and 3 being good)

Stage of project	RACER criterion					Score
	Relevance	Acceptability	Credibility	Ease	Robustness	
Task 4 (original RACER assessment)	3	2	3	2	2	12
After Task 5 (following testing)	3	3	2	2	1	11

3.3 CHALLENGES AND LESSONS LEARNED

3.3.1 Challenges

The key challenges with the monitoring of the indicator included:

Availability of data

- As stated in the data collection plan, there was an initial aim to evaluate the share of organic fertiliser used at a company level as well as a regional level, however the indicator could only be assessed at a regional level due to the unavailability of company-specific data.
- Securing regional level data for many EU Member States was also a challenge. For this reason, the indicator boundary changed from Austria to Germany, because Germany was one of the few EU countries that publishes regional data.

Language barrier

- National statistics on fertiliser consumption were often not available in English, requiring unexpected time translating datasets from the original language into English.

Comparing regional datasets

- There was no uniform scope for measurement of organic fertiliser use. This report defined organic fertiliser as animal materials only, but available organic data did not always clarify this distinction meaning it sometimes included other organic waste (e.g. green waste such as compost).

Reluctance of companies to share data

- Companies engaged with had concerns about sharing data due to concerns over data privacy and competitiveness. This may significantly limit access to detailed operational data for the indicator.

Integration of biowaste treatment into broader CE models

- Effectively integrating biowaste treatment into broader circular economy models requires understanding beyond mere treatment percentages. It involves assessing the quality and usability of the by-products (biogas and biofertiliser) and their market dynamics.

3.3.2 Lessons learned

The key lessons learned included:

- Allow more time to validate the methodology and conduct brief consultations with agricultural experts to ensure it is a robust method for measuring the share of organic fertiliser used.

- Allow for a more extended data collection period to improve the dataset, assess the breakdown of fertiliser according to land type, and carry out a more thorough stakeholder engagement to corroborate findings and minimise data gaps.
- Importance of cross sector collaboration. Engaging with a broader array of stakeholders, including academia, non-governmental organisations and the public sector may provide alternative avenues for data collection and validation.
- The challenges encountered underscore the need for supportive policy frameworks that mandate or incentivise the reporting of relevant data. Policy may be needed to help overcome data gaps and foster a more cooperative environment among industry players.

3.4 CONCLUSIONS AND RECOMMENDATIONS

It is recommended that this indicator is considered for further development, with significant work required to facilitate its progress

This indicator is promising for adoption across EU Member States due to its significance in measuring the circular bioeconomy. It emphasises the use of organic fertilisers facilitating the reintroduction of materials into the environment, closing carbon and nutrient cycles[31]. The proportion of organic fertiliser usage demonstrates how organic waste is repurposed for agriculture, enhancing soil quality instead of being incinerating it or sent to landfill. It also indicates the rate at which fossil-based products such as Synthetic fertilisers are being replaced, reducing the carbon footprint of the agriculture sector.

The indicator is also widely accepted by stakeholders, as it aligns with the EU's Farm to Fork strategy (EC, 2020) targets to help farmers optimise their fertiliser use while securing yields by substituting Synthetic fertilisers with organic fertilisers whenever possible[32]. Measuring the use of organic fertilisers will also be required to monitor the progress of Member States' CAP Strategic Plans, which are used as a tool to reduce the EU's agricultural sector's dependence on synthetic fertilisers (EC, 2023).

However, the testing phase of indicator revealed that methodological refinements are necessary to improve the indicator's accuracy and robustness. A significant finding was that measuring organise fertiliser usage by weight does not provide accurate comparisons with Synthetic fertilisers due to their differing nutrient densities. The testing phase also highlighted challenges in replicating the methodology across Member State regions with inconsistencies in data on organic and Synthetic fertiliser consumption was not always available and proxy data (e.g. using average fertiliser application rates) needed to be used. One key limitation of this indicator is that further assessment of the quality and usability of the by-products (biogas and biofertiliser) and their market dynamics is required as part of the development of this indicator to effectively integrate biowaste treatment into broader circular economy models.

It is recommended that further research is conducted to find an average ratio to apply to the amount of organic fertiliser applied to obtain an accurate comparison with the volume of Synthetic fertiliser. This could require extensive stakeholder engagement with agricultural bodies and farmers given variations in application practices and agricultural land types (i.e. grassland, cropland and pasture).

Alternatively new methodologies could be explored to monitor the indicator, such as measuring the market share of organic fertiliser and Synthetic fertiliser in financial terms. Potential limitations of this method may be that many farmers do not purchase organic fertiliser, instead creating their own compost to reduce the cost of purchasing Synthetic fertilisers meaning some organic fertiliser would not be accounted for in the data.

Additional recommendations include providing financial incentives to farmers for better data collection on fertiliser use which will support the establishment of a more reliable comparison framework and sharing of best practices. Accurate measurements would also allow the EC, policymakers and farmers to identify where efficiencies can be made and allow for more targeted interventions. However, we suggest establishing a threshold so that only large farms are required to collect data in order to avoid additional burden on small farms. This is because it was not deemed realistic to ask small farms to efficiently collect data to measure this indicator. Further investigation into whether the value and feasibility of including cover crops and green manure should be considered so as to create a more complete indicator.

[31] Compost Network, Circular Bioeconomy <https://www.compostnetwork.info/policy/circular-economy/> [Accessed February 2024]

[32] European Comission, Agriculture and Rural Development <https://agriculture.ec.europa.eu/common-agricultural-policy/agri-food-supply-chain/ensuring-availability-and-affordability-fertilisers_en> [Accessed February 2024]

Following the testing of this indicator, it was found that its original name ‘The quantity of organic fertiliser used as a proportion of overall fertiliser use in agricultural practices’ was fit for purpose and that no variation was needed.

In summary, the development of this indicator would help to monitor progress towards the EU’s Farm to Fork Strategy and target for 25% of agricultural land to be organic by 2030. The transition to organic farming is a necessary step towards creating a circular bioeconomy, as it closes nutrient cycles, creates healthier soils for storing carbon and retaining water, minimises waste, enhances biodiversity and reduces the EU’s dependence of non-renewable resources such as synthetic fertilisers and fossil fuels.

Table 17: Summary of recommendations for indicator B3

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
Development of a more robust methodology	The methodology needs to be refined by applying a standard ratio to the tonnage of organic fertiliser applied for a previse comparison with Synthetic fertilisers. Another option would be measuring the market share of organic fertilisers instead. These methods should be standardised across regions and could make use of technology such as remote sensing to streamline the process.	Credibility, Ease and Robustness	Medium (1.5 – 5 years)	Responsible: EC Accountable: EC Consulted: Farmers and industry associations Informed: Farmers, industry associations and the public
Financial support	Provide greater financial support to large farms to meet data collection requirements, such as investing in new technologies and infrastructure for organic fertiliser management to support the transition to organic farming. Establish incentive programmes to encourage large farms to switch to organic fertilisers whilst supporting them with the data collection. This could include subsidies for organic purchases or tax breaks.	Credibility and Ease	Medium (1.5 – 5 years)	Responsible: EC Accountable: EC Consulted: Member States and farmers to understand requirements Informed: Farmers, industry associations and the public
Support with data collection	Develop harmonised and robust systems for collecting data on fertiliser use and nutrient use, allowing for the exchange of best practice and sharing of information.	Credibility, Ease and Robustness	Medium (1.5 – 5 years)	Responsible: EC Accountable: EC Consulted: Farmers and industry associations Informed: Farmers and industry associations
Step-by-step approach to develop and test new methodology	Given the issues identified with the current methodology, a step-by-step approach to developing and testing a new methodology is recommended. This could include pilot studies, consultations with agronomy experts, and the integration of technological advancements for data collection.	Credibility, Ease and Robustness	Medium (1.5 – 5 years)	Responsible: EC Accountable: EC Consulted: Farmers and industry associations

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
				Informed: Farmers and industry associations

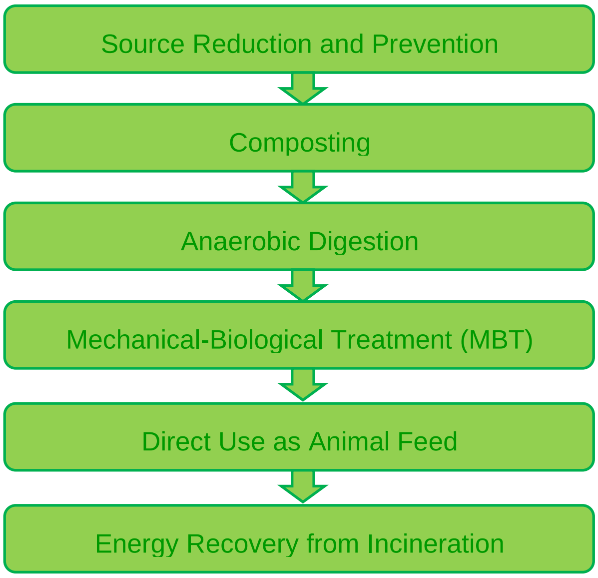
4. INDICATOR 3 - SHARE OF BIOLOGICAL WASTE TREATED WITH ANAEROBIC DIGESTION

The aim of this indicator is to calculate the share of biological waste being treated through Anaerobic Digestion (AD), resulting in the production of biogas and biofertiliser, at a regional and company level.

This indicator is relevant to the CE as it makes use of a waste product in the form of biological waste from agriculture, residential and forestry sources, and uses it as a feedstock in a closed-loop system to produce valuable products like biogas and biofertiliser. As of 2020, biological waste, referred to as biowaste and defined as waste material derived from organic matter, accounted for 34% of solid municipal waste generated in the EU (European Environment Agency, 2020). Therefore, recycling biowaste is critical in order for the EU to meet its target of recycling 65% municipal waste by 2035 (European Environment Agency, 2020).

Figure 6 shows the widely accepted hierarchy of biological waste treatment methods from most to least preferable (Zero Waste Europe, 2016). As the second form of waste treatment of this hierarchy, AD is the most desirable form of treatment for biological waste where composting is not suitable. The monitoring of AD levels is therefore valuable but must be undertaken alongside the monitoring of other forms of biological waste treatment in accordance with the treatment hierarchy.

Figure 6 - Hierarchy of biological waste treatment methods from most to least preferable



There are many benefits to monitoring this indicator, for example:

- Ensuring the resource efficiency of biological waste.
- Promoting resource efficiency and mitigating climate change impacts.
- Supporting sustainable agriculture practices and closing nutrient loops within food production systems.
- Assessing progress of the EU towards its CE objectives, renewable energy targets, and environmental sustainability goals.

4.1 KEY METHODOLOGY

4.1.1 Testing method

This indicator was measured at a regional and company level, limited to the regions of Berlin, Baden-Württemberg and Saarland in Germany and Malta and Gozo in Malta. The countries of Germany and Malta were selected as they represent the EU countries with the highest and lowest output of AD respectively (EurObserver, 2022).

The following regions of Germany were selected as they represent a good mix of urban, rural high and low population areas.

- **Berlin** is a small, highly urbanised region comprised mainly of the city of Berlin and surrounding urban areas. It had a population of 3,755,251 as of 2022 [33]
- **Baden-Württemberg** is the third-largest state of Germany by land area and has a large population of 11,280,257 as of 2022[34]. It contains the large cities of Stuttgart, Karlsruhe and Mannheim but is mainly comprised of rural areas.
- **Saarland** is the fourth smallest by land area (smallest non-city state) and second least populated German state, with a population of 992,666 as of 2022[35]. The only major town is Saarbrücken.

The regions of Malta and Gozo were selected for Malta as they together represent the whole country and contribute all the input to Malta's sole AD plant.

4.1.2 Data collection method

Due to the lack of readily available online data, the data collection method for this indicator primarily involved stakeholder engagement following by material flow analysis once appropriate data was identified.

Stakeholder engagement

To expand the research, the national statistics agencies of Czechia[36], Romania[37], Cyprus[38] and Denmark[39] were contacted in addition to Germany and Malta as these countries were amongst the highest or lowest outputs of AD (EurObserver, 2022). This outreach was necessary as the initial attempts to engage stakeholders yielded limited responses. Additionally, several companies considered industry leaders in AD were also contacted.

The stakeholders were approached through email, online query forms or telephone calls in which the project objectives were outlined, and the specific data needs were detailed. The information requested included:

- Data on the total production of biogas and/or biofertiliser generated through AD by either region or company.
- The total amount of biowaste produced, either broken down by region or by company.

The data was requested for as many years as available. Up to two reminder emails were sent to non-responding stakeholders. A detailed record of all stakeholder communications, including dates of initial contact and follow-up attempts was maintained in a MS Excel spreadsheet. This can be found in Appendix 5.8.

The same process was repeated in attempts to engage with leading corporate stakeholders which were selected during desk-based research. Full details of the companies contacted, and their responses, or lack thereof, can be found in Appendix 5.8.

Material flow analysis

Following the stakeholder engagement , a material flow analysis was conducted. This consisted of quantifying the volume of biowaste generated within the defined region using the data collected during the engagement campaign.

Table 18 below summarises the data collected to build this indicator.

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[33] Destatis, Countries and Regions <https://www.destatis.de/EN/Themes/Countries-Regions/Regional-Statistics/_node.html> [Accessed March 2024]

[34] <https://www.destatis.de/EN/Themes/Countries-Regions/Regional-Statistics/_node.html> [Accessed March 2024]

[35] <https://www.destatis.de/EN/Themes/Countries-Regions/Regional-Statistics/_node.html> [Accessed March 2024]

[36] Czech Statistics Agency <https://www.czso.cz/csu/czso/statistics> [Accessed February 2024]

[37] Institutul National de Statistica <https://insse.ro/cms/ro/content/formular-de-contact> [Accessed February 2024]

[38] CY Statistical Service <https://www.cystat.gov.cy/en/default> [Accessed February 2024]

[39] Statistics Denmark <https://www.dst.dk/en/%20> [Accessed February 2024]

Table 18 - Data Source Table

#	Source	Data collected	Reliability*	Availability**
1	Destatis[40]	Stakeholder engagement and desk-based research: • Data on total municipal biowaste generated and total municipal biowaste treated by AD provided for the whole of Germany. • Data on total municipal biowaste generated per region in Germany.	High	Medium
2	NSO Malta[41]	Stakeholder engagement: • Data on total waste containing food waste collected by category in Malta's two regions for the years 2021 and 2022 and the inputs and outputs of the sole AD plant operating in Malta for the two years.	High	High

** **Low** = Some data was missing and incomplete, which may lead to inaccurate conclusions, **Medium** = The data was complete but may lack accuracy and quality, **High** = The data was complete, accurate and of high quality.*
*** **Low** = The data was not already collected or readily available, and was difficult to collect. **Medium** = The data was already collected but was not publicly available, OR the data was not already collected but was easy to collect, **High** = The data was readily available and was accessed easily.*

4.1.3 Calculations

Using the data collected, the flow of biowaste from collection points to AD facilities, where organic materials are processed to produce biogas and biofertiliser, was traced and the share of biowaste treated using AD in the defined regions was calculated.

The following calculations were completed in MS Excel:

- **Germany**: Calculations were completed using national level data due to the lack of regional waste treatment data and company-level data. Using the data from Destatis (Table 21), it was calculated that the share of German municipal biowaste treated in 2022 was approximately 100% (99.98%). This finding was used to create the assumption that all German municipal biowaste is treated using AD. This assumption was then applied to the data in Table 22, which contains a breakdown of total German municipal biowaste collection by region for 2021 to estimate the share of each region's biowaste treated using AD.
- **Malta**: Using the data from NSO Malta (Table 23), the total input of organic waste into Malta's sole AD plant was divided by the total amount of waste collected containing food waste, to estimate the share of biowaste being treated by AD. Data was provided split by region for both the AD plant input and waste collection data.

The details of the calculations can be found in Appendix 5.7.

[40] <https://www.destatis.de/EN/Home/_node.html> [accessed February 2024]

[41] NSO Malta <https://nso.gov.mt/> [accessed February 2024]

4.1.4 Timeline

Table 19 below presents the timeline of the testing of this indicator.

Table 19. Gantt chart showing testing timeline

w/c	15/01	22/01	29/01	05/02	12/02	19/02	26/02	04/03	11/03	18/03	25/03
Define system boundary											
Desk-based research											
Stakeholder engagement											
Develop methodology											
Case study writing											
Review period											
Key deliverables											

Data gaps and mitigation

Table 20 below summarises the data gaps and mitigation.

Table 20. Overview of identified data gaps, limitations and mitigation efforts

	Description of data gap	Mitigation efforts	Level of confidence
1	Commercial and Industrial biowaste data was not available for Germany.	Substantial effort was made to obtain Commercial and Industrial data but only municipal data for biowaste was available. Therefore, only municipal (household) data was evaluated for this indicator.	High
2	Amount of municipal biowaste sent to AD was not available for German regions.	Data collected at national level showed that Germany sends 100% of its municipal biowaste to AD. Therefore this share was applied to the regional data collected.	High
3	National data for Germany was only available for 2022, whereas the regional data was only available for 2021.	As the rate of municipal biowaste treated with AD was found to be 100% in 2022, it was assumed that this was also true for 2021.	Medium
4	No company level data was available due to insufficient engagement from stakeholders.	• Effort was made to contact the leaders of the European AD industry. Ten of the top companies for AD output were identified by desk-based research and all were contacted via email or telephone to the relevant departments of each company. • As no data was obtained from any company, it was not possible to mitigate	Low

	Description of data gap	Mitigation efforts	Level of confidence
		this data gap and therefore, this indicator could not be measured at company level.	
5	Data that is included for Malta comprises EWC codes that refer to waste that contain food waste. Certain EWC codes are made up of 100% food waste however, other codes comprise food waste that is mixed with other waste materials. Therefore the findings do not refer to food waste generation but only to those waste types which contain food waste.	• It was not possible to identify the share of food waste contained in each EWC[42] code therefore 100% of the data provided was assumed to be biowaste. This means that the amount of biowaste collected was overestimated.	Low

Quality review of analysis

To maintain strong and reliable outcomes, the following procedures for data validation and quality control were implemented:

- The Project Director assessed the proposed research methodology before commencement to ensure its suitability for the task. After addressing any feedback, the research team proceeded to data collection.
- The Project Manager or an appointed representative conducted a thorough review of the completed work.
- The Quality Assurance Manager oversaw the final case study output's quality. The Project Manager collaborated with the Quality Assurance Manager to evaluate the output's quality and recommend enhancements.

[42] Note: (European Waste Catalogue) codes are standardized classification codes used to categorise and manage various types of waste generated within the European Union.

4.2 KEY ANALYSIS RESULTS

4.2.1 Analysis

Germany

The share of national municipal biowaste treated using AD can be found in Table 21. This data was used to assume that 100% of the regional municipal biowaste in Germany is treated with AD, a finding which was then applied to the regional data for 2021.

Table 21 - Share of municipal biowaste treated by AD in Germany in 2022

Total biowaste collected (tonnes)	Total treated by AD (tonnes)	*Percentage* treated by AD
11,328,000	11,326,000	100.0%

Table 22 below presents the results of the calculating of the share of biological waste treated with AD for Germany at regional level.

Table 22 – Share of regional municipal biowaste treated by AD in Germany in 2021

Region	*Municipal Biowaste Collected 2021 (tonnes)*	*Percentage treated with AD*
Baden-Württemberg	1,679,056	*100%*
Saarland	134,722	*100%*
Berlin	139,360	*100%*

The data indicates that Germany treats virtually 100% of its municipal biowaste with AD in 2022. This uniform application across all regions suggests a well-developed, nationwide infrastructure for biowaste management that is both efficient and sustainable. The uniformity in the share of biowaste treated with AD across diverse regions, from densely populated areas like Nordrhein-Westfalen to rural areas like Mecklenburg-Vorpommern, highlights the scalability and adaptability of Germany's waste management systems.

Malta

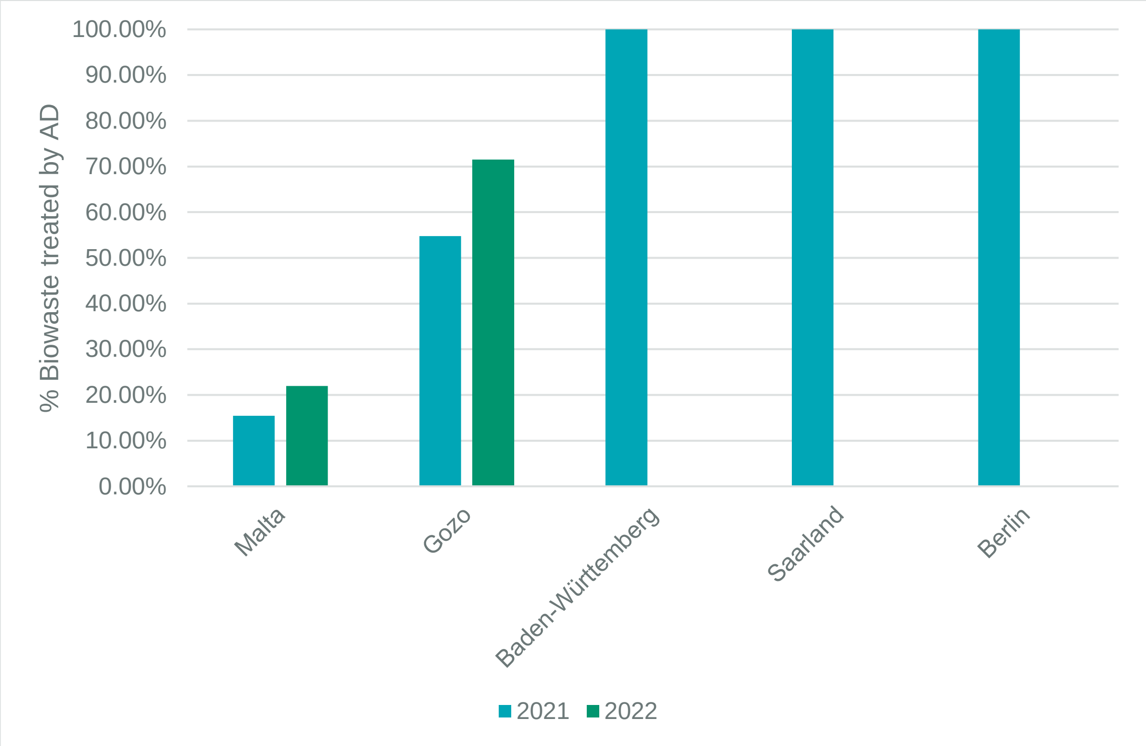
Table 23 below presents the share of biological waste treated with AD for Malta at regional level, with Figure 7 representing it graphically.

Table 23 – Share of regional biowaste treated by AD in Malta in 2021 and 2022

	Malta 2021	Gozo 2021	Malta 2022	Gozo 2022
Total Municipal Biowaste collected (tonnes)	173,165.91	12,312.90	187,252.54	12,702.42
Total Treated by AD (tonnes)	26,773.53	6,744.14	41,146.12	9,082.83
Percentage treated by AD	15.46%	54.77%	21.97%	71.50%

The data from Malta shows a contrast in the share of biowaste treated with AD between Malta and Gozo, with Gozo consistently showing a higher percentage. This could indicate differences in regional waste management policies.

Figure 7 - Share of biowaste treated by AD across German and Maltese regions for the years 2021 and 2022.



The difference in the percentage of biowaste treated with AD between Germany (100%) and Malta (ranging from 15.46% to 71.50%) highlights the varying stages of AD technology adoption and infrastructure development in European countries.

4.2.2 Limitations

The main limitations of this indicator are :

- **Lack of company-supplied data:** Efforts to obtain data from 10 leading companies in AD were unsuccessful despite attempts to follow up. The inability to find a suitable proxy for this missing data is noted as a significant outcome of the indicator testing phase.
- **Low company engagement:** Only two of the companies contacted as part of the stakeholder engagement provided any response, and neither was willing to contribute data. This suggests a general disinterest in participating in the project.
- **Incomplete biowaste stream data for Germany:** Data specific to commercial and industrial waste streams in Germany could not be sourced. As such, the analysis was limited to only biowaste from municipal (household) collection and the treatment of this waste.
- **Unavailability of specific biowaste data for Malta:** The received data encompassed all waste categories containing food waste, rather than being specific to biowaste. As such, it is likely that the total biowaste has been overestimated.

4.2.3 Performance

Table 24 below shows that the indicator received a lower score in the RACER evaluation following testing compared to the original assessment. Details on the scoring are available in Appendix 5.1. The updated scoring was based on the following considerations:

- **Relevance**: The indicator is closely linked to the objective of measuring circularity in the bioeconomy (treating waste with AD which could otherwise go to landfill or a less desirable method of waste treatment) and is therefore relevant to this project. The score was therefore left unchanged.
- **Acceptability**: Data on this indicator is already collected and used by policymakers and industry. AD has been highlighted as a priority for biowaste treatment at a national level in Germany, illustrated by

the near complete adoption of AD as the waste treatment method for municipal biowaste. As it has clearly been widely accepted at a national level, the maximum Acceptability score was assigned.

- **Credibility**: The data collected was incomplete as no regional or company level data was available and the biowaste data which was obtained represented only municipal biowaste or biowaste which could not be separated completely from other waste streams. Therefore, the credibility score was lowered from 3 to 2.
- **Ease**: The data is readily available at a national level and easily accessible through a data request to the relevant national statistical agency in most cases, but obtaining regional level data and company level data is difficult. The score was therefore left unchanged.
- **Robustness**: Due to the limitations described in Section 4.2.2, the results of the indicator lack robustness and the score was lowered from 2 to 1.

Table 24. RACER evaluation

Stage of project	RACER criterion					Score
	Relevance	Acceptability	Credibility	Ease	Robustness	
Task 4 (original RACER assessment)	3	2	3	2	2	12
After Task 5 (following testing)	3	3	2	2	1	11

4.3 CHALLENGES AND LESSONS LEARNED

4.3.1 Challenges

The primary difficulty encountered during the development of this indicator arose during the data gathering phase. Although national level data was readily available and easily obtainable through desk-based research, neither regional level data nor company level data was obtainable in this way. The challenge was partially mitigated by the use of national data as a proxy for calculating the share of regional biowaste treated with AD in Germany. However, it was not possible to mitigate against the absence of available data for company level, resulting in the inability to calculate this aspect of the indicator.

Another challenge arose with the data for Malta, which encompassed all waste types containing food waste. This broad categorisation meant that some of the accounted waste might not actually be biowaste, and distinguishing biowaste from other types of waste in this dataset was not feasible.

4.3.2 Lessons learned

The process of developing this indicator highlighted the need for enhanced data collection methods. Tracking the share of biowaste being treated by AD at a regional level will require Member State government agencies to maintain more detailed records for waste treatment, with a focus on regional specifics. This appears to be feasible as many waste-related data categories are already monitored at this level. As such, minor changes to policy and procedure could support this change.

Some work is required in order to support data collection and reporting at company level. A key insight from this project is the current lack of engagement among AD companies in tracking this specific indicator, coupled with their inability to supply the needed data. It is therefore expected that targeted legislation or government initiatives to encourage reporting would be needed to improve the availability and quality of the data.

4.4 CONCLUSIONS AND RECOMMENDATIONS

It is recommended that this indicator is considered for further development, with minor work required to facilitate its progress.

It is expected that this indicator holds significant importance for countries striving to advance towards a CE. By quantifying the volume of biowaste treated through AD, regions can assess the effectiveness of their waste management approaches and track progress towards achieving CE goals. Understanding the scale of biowaste diversion from landfills to AD facilities provides valuable insights into waste reduction efforts and resource recovery, ultimately contributing to the transition to a more CE.

As most regional governments and Member States already collect waste-related data, it is expected that only very minimal adjustments to the data collection protocols will be required for this indicator. In many cases it may be sufficient to expand data collection practices which already exist at the national level to both regional and company level to achieve the required development.

The significance of this indicator is underscored by Germany's approach, where 100% of municipal biowaste is processed via AD, showcasing the country's leadership in waste management globally[43]. Germany's commitment to AD for biowaste treatment reflects the indicator's value for advancing CE goals. An important future direction would be to evaluate the adoption of AD and determining if Germany's high adoption rate is mirrored across other Member States.

Following the testing of this indicator, it was found that its original name 'Share of biological waste treated with anaerobic digestion' was fit for purpose and that no variation was needed.

This indicator holds significant relevance within the EU's CEMF due to its multifaceted contributions to environmental sustainability, renewable energy generation, and waste management. Treating biowaste through AD diverts organic waste from landfills, reducing methane emissions and mitigating environmental pollution and provides renewable energy sources, contributing to the EU's objectives for clean energy transition and reducing reliance on fossil fuels.

Furthermore, this indicator aligns with the EU's goals for promoting resource efficiency and mitigating climate change impacts. By harnessing biogas produced from AD, the EU can diversify its energy mix, enhance energy security, and reduce greenhouse gas emissions. Additionally, the biofertiliser generated through AD can serve as organic fertilizer, supporting sustainable agriculture practices and closing nutrient loops within food production systems. Through monitoring frameworks that track AD adoption, organic waste treatment volumes, biogas production, and environmental outcomes, the EU can assess progress towards its CE objectives, renewable energy targets, and environmental sustainability goals.

[43] https://earth.org/waste-management-germany/

Table 25: Summary of recommendations

Type of recommendation	Recommendation	RACER criteria addressed	Timeline	Key stakeholders or partners
Development of data collection	Enhance the collection and publication of biowaste data at both the regional and company levels by national statistical agencies	Credibility, Ease and Robustness	Short (0.5-1.5 years)	Responsible: EC Accountable: EU state members Consulted: Relevant trade bodies Informed: Relevant companies
Legislation	Broaden data collection efforts to include all biowaste streams, such as agricultural waste, which are not typically monitored as closely as municipal waste streams	Credibility, Ease and Robustness	Medium (1.5 – 5 years)	Responsible: EC Accountable: EU state members Consulted: Relevant trade bodies Informed: Relevant companies
Economic or commercial incentivisation	Foster greater participation from companies in the monitoring of this indicator through economic or commercial incentives such as subsidies for new AD plants or Feed-in Tariffs.	Credibility, Ease and Robustness	Medium (1.5 – 5 years)	Responsible: EC Accountable: EU state members Consulted: Relevant trade bodies Informed: Relevant companies .
Develop Engagement Mechanisms	Enhance engagement mechanisms with all stakeholders involved in biowaste generation and AD treatment. This could include regular workshops, forums and feedback sessions to understand data challenges and improve reporting willingness and accuracy.	Credibility, Ease and Robustness	Short (0.5-1.5 years)	Responsible: EC Accountable: EU state members Consulted: Relevant trade bodies Informed: Relevant companies
Standardise data reporting format	Develop and implement standardised data formats and reporting protocols for biowaste and AD operation data to ensure consistency and comparability across regions, Member States and companies.	Ease	Short (0.5-1.5 years)	Responsible: EC Accountable: EU state members Consulted: Relevant trade bodies Informed: Relevant companies
Education and training	Develop and provide targeted training programme for stakeholders at the regional and company levels on data collection, reporting standards, and the importance of accurate data and encourage the adoption of best practices in data management.	Credibility	Medium (1.5 – 5 years)	Responsible: EC Accountable: EU state members Consulted: Relevant trade bodies Informed: Relevant companies

5. APPENDICES

5.1 RACER MATRIX

Criterion	Description	1 (Poor)	2 (Neutral)	3 (Good)
Relevance	Refers to whether the indicator is closely linked to the objectives to be reached.	Does not support a better understanding of true circularity.	Supports a better understanding of true circularity.	Highly supportive towards gaining a better understanding of true circularity.
		Supports no value-added circular opportunities.	Supports lower value-added opportunities (i.e. metrics related to waste generation, recycling, waste management, etc.)	Supports higher value-added opportunities (i.e. all R-strategies above remanufacturing) and wider systemic change (e.g. indicators that encourage PSS or circular design).
		Not linked to the project objectives and/or European policy objectives (existing or upcoming).	Linked to the project objectives, but not to European policy objectives (existing and/or upcoming).	Fully aligned with project objectives and European policy objectives (existing and/or upcoming).
Acceptance	Refers to whether the indicator is perceived and used by key stakeholders (such as policymakers, civil society, and industry).	Poorly accepted by key stakeholders, e.g. due to the use of confidential data.	Relatively accepted by key stakeholders as the benefits of measuring are clear.	Key stakeholders are motived to report this indicator, due to mandatory legislative requirements (current or upcoming), potential commercial benefit or being in the public interest.
Credibility	Refers to whether the indicator is transparent, trustworthy and easy to interpret.	No defined methodology associated with this indicator and/or interpretation of the indicator is ambiguous.	Methodologies have been proposed or currently existing, but not for this particular indicator (e.g. in a research article).	There is an EU defined methodology.
		Difficult to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders are not familiar with).	Moderately easy to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders are aware of but are not confident in practical use).	Easy to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders already use and are confident in applying).
Ease	Refers to the easiness of measuring and monitoring the indicator.	No defined methodology associated with this indicator and/or interpretation of the indicator is ambiguous.	Methodologies have been proposed or currently existing, but not for this particular indicator (e.g. in a research article).	There is an EU defined methodology.
		Difficult to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders are not familiar with).	Moderately easy to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders are aware of but are not confident in practical use).	Easy to understand and communicate to stakeholders (e.g. units or measurement of something that stakeholders already use and are confident in applying).
Robustness	Refers to whether data is biased and comprehensively assesses circularity.	No consistent methodology and dataset are available.	A consistent methodology and dataset available.	A consistent methodology and dataset available.
			A composite/aggregated indicator (based on multiples dimensions).	A one-dimensional indicator.
			A proxy indicator.	

5.2 INDICATOR 1 – EXAMPLE OF EMAIL SENT TO STAKEHOLDERS

Von: Sutcliffe, Laura <Laura.Sutcliffe@ricardo.com>
Datum: Montag, 22. Januar 2024 um 12:20
An: Dietz, Frank <dietz.frank@agscm.com>
Cc: Florian Von Hirsch <florian@vonhirsch.uk>
Betreff: RE: Measuring circularity across the EU

Thank you for putting us in touch, Florian!

Dear Frank,

Thank you for offering to speak to me regarding my project, supporting DG-RTD to develop and test new indicators for measuring circularity across the EU. I am so grateful! A link for more details on the study can be found here: Indicators and methods for measuring transition to climate-neutral circularity, its benefits, challenges and trade-offs'.

As Florian may have mentioned, I am measuring and testing a new indicator for the bioeconomy: 'the share of local agriculture and forestry waste by-products going to energy'. It has been agreed to measure this on a) a regional level and b) an organisational level, selecting Bavaria as one of the testing regions.

This means collecting two data points at each level:

- The total amount of local agriculture and forestry waste by-products
- The total amount of local agriculture and forestry waste by-products going to energy

I see from the BaySF website that you sell between 700,000-900,000 cubic meters of forest chips as biomass for heating plants. As part of the board, I would appreciate any help you are able to provide. Whether this be feedback on the aim of the indicator, advice and insight on how to gather the data, or provision of data itself (providing BaySF already collect it). Your experience and expertise will help us hugely.

Would you be available for a 30-minute call to discuss further? I can send you a Teams invite or we can speak over the phone, whichever is easiest for you.

Many thanks in advance.

Kind regards,

Laura

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5.3 INDICATOR 1 - DATA

See MS Excel document "DGRTD_B2_Data_V01.00" provided alongside this report.

5.4 INDICATOR 1 – LIST OF STAKEHOLDERS ENGAGED

See MS Excel document "DGRTD_B2_StakeholderEngagementTracker_V01.00" provided alongside this report.

5.5 INDICATOR 2 – DATA

See MS Excel document "DGRTD_B3_Data_V01.00" provided alongside this report.

5.6 INDICATOR 2 – LIST OF STAKEHOLDERS ENGAGED

See MS Excel document "DGRTD_B3_StakeholderEngagementTracker_V01.00" provided alongside this report.

5.7 INDICATOR 3 – DATA

See MS Excel document "DGRTD_B8_DataGermany_V01.02" for German data and calculations and MS Excel Document " DGRTD_B8_DataMalta_V02.02" for Maltese data and calculations provided alongside this report.

5.8 INDICATOR 3 – LIST OF STAKEHOLDERS ENGAGED

See MS Excel document "DGRTD_B8_StakeholderEngagementTracker_V01.02" provided alongside this report.

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