INDICATORS AND METHODS FOR MEASURING TRANSITION TO CLIMATE NEUTRAL CIRCULARITY

Task 5: Case-study group 2

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

Ref. RTD/2022/OP/0003

Ricardo, Gemini Building, Fermi Avenue, Harwell, Oxfordshire, OX11 0QR, UK | +44(0)1235 75 3000 | www.ricardo.com
Registered company no. 08229264 | VAT no. GB 212 8365 24

Customer:
European Commission, DG RTD

Customer reference:
RTD/2022/OP/0003

Confidentiality, copyright and reproduction:

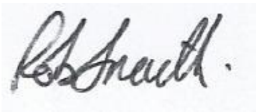
Contact:
Rob Snaith, 18 Blythswood Square, Glasgow, G2 4BG

T: +44 (0) 1235 753 029
E: rob.snaith@ricardo.com

Authors:
Carys Jones, Jacob Smith and Joe Salkeld,

Approved by:
Rob Snaith

Signed



Ricardo reference:
ED16719

Date:
30th August 2024

Ricardo is certified to ISO9001, ISO14001, ISO27001 and ISO45001.

CONTENTS

1. INTRODUCTION 2
2. INDICATOR 1: IMPACTS OF DIFFERING FOOD CONSUMPTION ON EUROPEAN BIODIVERSITY THROUGH POTENTIAL SPECIES LOST 3
   2.1 KEY METHODOLOGY 3
   2.2 KEY ANALYSIS RESULTS 9
   2.3 CHALLENGES AND LESSONS LEARNED 11
   2.4 CONCLUSIONS AND RECOMMENDATIONS 13
3. INDICATOR 2: 'WATER FOOTPRINT OF PRIVATE CONSUMPTION, AT NATIONAL LEVEL'. 15
   3.1 KEY METHODOLOGY 15
   3.2 KEY RESULTS 24
   3.3 CHALLENGES AND LESSONS LEARNED 26
   3.4 CONCLUSIONS AND RECOMMENDATIONS 28
4. APPENDIX 33
   4.1 INDICATOR 1 – DATA 33
   4.2 ALL INDICATORS - RACER ASSESSMENT MATRIX 34
   4.3 INDICATOR 2 – DATASET AND CALCULATIONS 35
5. BIBLIOGRAPHY 36

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 'Households' 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 2 indicators outlined in Table 1-1.

Table 1-1. Overview of case-study Group 2

URN		Indicator name	Methodology	Level of implementation				
				EU	National	City / Region	Companies	Household
H2	**1**	Impacts of differing food consumption on European biodiversity through potential species lost.	Desk based research					x
H9	**2**	Water footprint of private consumption, at national level.	Desk based research					x

2. INDICATOR 1: IMPACTS OF DIFFERING FOOD CONSUMPTION ON EUROPEAN BIODIVERSITY THROUGH POTENTIAL SPECIES LOST

This indicator focuses on the impact of food consumption on biodiversity at a household level on a national scale. This indicator looks at how the varied diets and food production styles in Italy, Hungary and Romania can impact the biodiversity of these countries.

This is of significant relevance to the CE as food systems have a significant impact on biodiversity. Previously, food systems have been focused on cost rather than mitigating/reducing impacts on biodiversity[1]. The aim of this study is to identify the food sources with the largest negative impact on biodiversity which would allow the identification of areas to focus efforts on in the future to help reverse or minimise declines in biodiversity. This could include identifying better farming practices, varying products produced and changing consumption levels of certain products.

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

- Identifying food sources with high biodiversity impacts.
- Assessing trends across different Member States driving greater impact on biodiversity from food consumption.
- Identifying areas requiring further research.

This case study sets out the methodology, data collection, results, limitations and challenges, and conclusions to assess the household impact on biodiversity on a nation-level.

2.1 KEY METHODOLOGY

2.1.1 Testing method

The biodiversity impact indicator is focused on private food consumption by households. Different food sources have varying impacts on biodiversity through how they are produced, and the amount of land required to produce the food. As such the Product Environmental Footprint (PEF)[2] methodology is adopted for assessing the environmental impacts of different food sources, this methodology has been developed by the European Commission over the last two decades. The following parameters have been defined:

2.1.1.1 Spatial scope

Due to transnational variations within the EU Member States due to economic, social, cultural and environmental differences, three Member States have been selected to provide a range of different levels of prosperity, GDP, population density, farming practices, and climates and highlight the potential variability throughout the EU. These countries are Italy, Romania and Hungary. These nations differ in many ways including GDP per capita (as of 2022 Italy €28,250, Hungary €14,350 and Romania €10,030)[3], population (as of 2022 Italy – 58millon, Hungary – 9million and Romania – 19million[4]) and bioregions (Italy predominately Adriatic Sea & Central Mediterranean Mixed Forests (PA19), Hungary predominately Carpathian Mountain & Plains Mixed Forests (PA14) and Romania spread across four different bioregions[5]).

---

[1] Benton, T. Bieg, C. Hatwatt, H. Pudassaini, R. and Wellesly, L. (2021) Food system impacts on biodiversity loss Three levers for food system transformation in support of nature

[2] EU Commission (2021) Understanding Product Environmental Footprint and Organisation Environmental Footprint methods

[3] Eurostat, Real GDP per capita (ec.europa.eu, 2024) https://ec.europa.eu/eurostat/databrowser/view/sdg_08_10/default/table?lang=en accessed January 2024

[4] Eurostat, Population change - Demographic balance and crude rates at national level (ec.europa.eu, 2024) https://ec.europa.eu/eurostat/databrowser/view/demo_gind/default/table?lang=en accessed January 2024

[5] One Earth, Eco Regions (oneaearth.org, 2023) https://www.oneearth.org/navigator/ accessed January 2024

2.1.1.2 Temporal scope

Following a search of the different datasets available at the European Food Safety Authority[6] it was decided to use data that has been collated from the years 2018 - 2020 for use in this indicator. This time period was selected for a number of reasons as set out below:

- During this period 12 EU Member States carried out food consumption surveys as the number of countries carrying out surveys varies year to year.
- It avoids the majority of the Covid -19 pandemic period which may have skewed results.
- The data is still relatively recent being within the last ten years so should reflect current trends.
- No survey data has been published for surveys post 2020.

2.1.1.3 Data Scope

For this analysis two different food sources (beef and grain products) were focused on. These were selected for their differing impacts on biodiversity (through process of production and area required) while also being widely consumed products within the EU Member States[7].

2.1.2 Data collection method

For carrying out this testing method, four main data sources were used to provide information which are set out in Table 2-1. During the data collection process certain gaps in available data were identified and assumptions made to cover these, this is detailed in Section 2.1.5.

Table 2-1: Data sources used in testing method

Data Source	Data Collected
European Food Safety Authority (EFSA) www.efsa.europa.eu	Food consumption per person per day (in g/day) by food group (in this case beef and grain)
ec.europa.eu/eurostat/databrowser[8]	Average People per household by nation
www.ourworldindata.org Land use by food type data set[9]	Area of land required to produce the amount of the food group to be calculated in sq m per kg
Chaudhary, et al., 2015	Potential species loss/m^2 of land use
Joseph Poore and Thomas Nemecek (2018)	Area required to produce 1kg of a product.

2.1.2.1 Food consumption data

Data on "Food consumption per day" was gathered from the European Food Safety Authority (EFSA)[10] website where data from surveys across Europe are compiled from the surveys available on this website. Surveys in the appropriate time period were available from the following countries; Republic of North Macedonia, Italy, Hungary, Austria, Serbia and Romania. Austria was ruled out as the survey focused on adolescents, Serbia is not an EU member and Republic of North Macedonia is neither a member of the EU and used a different survey methodology to the others. The following three surveys were selected for use in this analysis:

---

[6] EFSA, Food consumption data (efsa.europa.eu, 2022) https://www.efsa.europa.eu/en/data-report/food-consumption-data accessed January 2024

[7] Stefan Wirsenius, Christian Azar, Göran Berndes,How much land is needed for global food production under scenarios of dietary changes and livestock productivity increases in 2030?,Agricultural Systems,Volume 103, Issue 9,2010,Pages 621-638,

[8]https://ec.europa.eu/eurostat/databrowser/view/ILC_LVPH01__custom_3603397/bookmark/table?lang=en&bookmarkId=5d2c2746-642e-498b-9699-33fd2f99b666

[9] Poore, J., and Nemecek, Land use by food type (our world in data,2018) , https://ourworldindata.org/land-use#land-use-by-food-type accessed December 2023

[10] EFSA, Food consumption data (efsa.europa.eu, 2022) https://www.efsa.europa.eu/en/data-report/food-consumption-data accessed January 2024

- Romanian national food consumption survey for adolescents, adults and elderly[11] here after referred to as the "Romanian Survey".
- Italian national dietary survey on adult population from 10 up to 74 years old[12] here after referred to as the "Italian Survey".
- Hungarian national food consumption survey[13] here after referred to as the "Hungarian Survey".

These surveys were all selected as they all took place in an overlapping time period of August 2019 to February 2020 with surveys extending either side of this time period, the full extent of each survey is set out in Table 2-2. Although the surveys covered a range of age groups only data from adults was used for this analysis. The EFSA[14] survey guidance categorises adults as 18 – 64 years old.

Table 2-2: Time range and number of people surveyed of food consumption surveys used for analysis.

Data Source	Start Date	End Dat	People Surveyed
Romanian Survey	26/08/2019	28/02/2020	740
Italian Survey	16/12/2018	18/12/2020	726
Hungarian Survey	11/05/2018	26/04/2020	529

These three surveys were also selected as they all used "Food record, 24-hours dietary recall". This involved participants being interviewed and asked to report the foods, beverages and food supplements consumed on the preceding day. Participants were interviewed twice with a minimum of eight days between interviews within the survey period. Interviews and data processing were carried out in line with the EFSA guidance[15] this includes grouping food using the FoodEx2 matrix[16]. FoodEx2 is a food classification and description system aimed at covering the need to describe food in data collections and ensures consistent recording across surveys[17]. An example of the classification levels used in FOOdEx2 is shown in Table 2-3, not all products require all seven hierarchy levels.

[11] Romanian National Sanitary Veterinary and Food Safety Authority, Romanian National Institute for Public Health, Neagu M, Nicolescu F, Tănăsescu B, Stan M, Zugravu C, Cucu A., Galan A., Partin A., 2020. Romanian national food consumption survey for adolescents, adults and elderly. EFSA supporting publication 2020: 17(9): EN-1923. 39 pp. doi 10.2903/sp.efsa.2020.EN-1923

[12] CREA-Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria - Centro di Ricerca Alimenti e Nutrizione. Turrini A., Le Donne C., Piccinelli R., D'Addezio L., Mistura L., Sette S., Martone D., Comendador Azcarraga F.J., Ferrari M., Catasta G., 2022. Italian national dietary survey on adult population from 10 up to 74 years old – IV SCAI ADULT. EFSA Supporting Publication 2022: 19(9):EN-7559. 39 pp. doi:10.2903/sp.efsa.2022.EN-7559

[13] National Food Chain Safety Office, Hungary, Csizmadia K, Larnsak L., Pfaff N., Sali J., 2020. Hungarian national food consumption survey on adults. EFSA supporting publication2020: 17(12):EN-1981. 26 pp. doi: 10.2903/sp.efsa.2020.EN-1981

[14] European Food Safety Authority, 2014. Guidance on the EU Menu methodology. EFSA Journal 2014; 12(12):3944, 77 pp. doi:10.2903/j.efsa.2014.3944

[15] European Food Safety Authority, 2014. Guidance on the EU Menu methodology. EFSA Journal 2014; 12(12):3944, 77 pp. doi:10.2903/j.efsa.2014.3944

[16] EFSA (European Food Safety Authority), Ioannidou S, 2019. EFSA Catalogue browser User Guide. EFSA Supporting Publication 2019:EN-1726. 46pp. doi:10.2903/sp.efsa.2019.EN-1726

[17] European Food Safety Authority, 2015. The food classification and description system FoodEx2 (revision 2). EFSA Supporting Publication 2015; 12(5):EN-804, 90 pp. doi:10.2903/sp.efsa.2015.EN-804

Table 2-3: Example of FoodeX2 Classifications

Hierarchy Level	Example 1	Example 2	Example 3
Exposure hierarchy (L1))	Meat and meat products	Grains and grain-based products	Grains and grain-based products
Exposure hierarchy (L2)	Animal other slaughtering products	Bread and similar products	Fine bakery wares
Exposure hierarchy (L3)	Mammals other slaughtering products	Leavened bread and similar	Cakes
Exposure hierarchy (L4)	Bovine other slaughtering products	Multigrain bread and rolls	Plain cakes
Exposure hierarchy (L5)	Bovine tongue	Mixed wheat and rye bread and rolls	Cream cake
Exposure hierarchy (L6)	Bovine tongue	Rye-wheat bread and rolls, wholemeal	Cheese cake
Exposure hierarchy (L7)	Bovine tongue	Rye-wheat bread and rolls, wholemeal	Cheese cream sponge cake

From the data provided in these surveys two food groups, grain and beef, were selected for comparison. These were chosen as they are widely consumed within Europe and therefore would have high enough respondents consuming to enable analysis while also having differing levels of environmental impact / footprint required cost and availability.

The data collected from EFSA was then filtered through all seven levels of the FoodEx2 exposure hierarchy[18] to ensure only appropriate data was used. The FoodEx2 system is used to facilitate the grouping of food items and reporting consumption. Where even at the seventh level of the hierarchy it was uncertain or ambiguous if the food product primarily contained either beef or grain then they were excluded. These exclusions were kept consistent across the data from all three national surveys (Section 2.1.5).

The data for the amount of land required to produce 1kg of each food type was taken from work carried out by Joseph Poore and Thomas Nemecek (2018)[19]. This work looked at the area required to produce the food source but also the supporting land. For example: for cattle while they may need X ha of grazing land, they may also require supplementary feeding which would require crops grown on additional land (assumed to be in the same country for the purpose of this indicator, see Section 2.1.5).

2.1.2.2 Occupancy data

The “Average People per household by nation” data was collected by Member State under the common framework for European statistics relating to persons and households established by the EU regulation 2019/1700 and set out in the EU regulation 2019/2180. This allows for the data to be comparable across all the states selected. To produce the “Average household occupancy” for the calculations, the average of the occupancies from 2016 to 2020 was taken for each country selected.

2.1.2.3 Biodiversity Impact data

The “Potential species loss/m^2” used data was taken from the peer reviewed paper by Chaudhary, et al., 2015[20] and the associated data sets provided by the authors. This paper expanded on the principal of “characterization factors” (CFs) which are factors indicating biodiversity damage per unit area of land use including agricultural

[18] European Food Safety Authority, 2015. The food classification and description system FoodEx2 (revision 2). EFSA Supporting Publication 2015; 12(5):EN-804, 90 pp. doi:10.2903/sp.efsa.2015.EN-804

[19] Poore, J., & Nemecek, T. (2018). Reducing food’s environmental impacts through producers and consumers. Science. – processed by Our World in Data

[20] Chaudhary A, Verones F, de Baan L, Hellweg S. Quantifying Land Use Impacts on Biodiversity: Combining Species-Area Models and Vulnerability Indicators. Environ Sci Technol. 2015 Aug 18;49(16):9987-95. doi: 10.1021/acs.est.5b02507. Epub 2015 Jul 31. PMID: 26197362.

land. This paper produced more accurate assessments of CFs taking into account broader ranges of habitats, varied species scarcity, the statistical unlikeliness of extinction and also used updated taxon sensitivity data. This data relates to likely different species groups are likely to be impacted by change. This paper produced data for different intensity levels of farming classified as “high”, “medium” and “low”[21] based on their impacts. The data was compared at all three intensity levels although in reality food production in all countries will be a mix of intensities.

2.1.3 Calculations

The main calculation used in order to establish the potential Species Lost per Household (SPH) from the consumption of different food groups is:

$$SLPH=(([gperP \times HO] \div [AR \div 1000]) \times SPH) \times 10000$$

gperP = g consumed per person.
HO= Average household occupancy.
AR= Area required to produce kg.
*SPH= Potential species loss*years/m2.*
SLPH = Species lost per household.

2.1.4 Timeline

The time frame for the completion of the project is set out in Table 2-4.

Table 2-4: Gantt Chat of Project Plan

WC	18-Dec	25-Dec	01-Jan	08-Jan	15-Jan	22-Jan	29-Jan	05-Feb	12-Feb	19-Feb	26-Feb	04-Mar	11-Mar	18-Mar	25-Mar	01-Apr
Task 1 - Data Collection																
Task 2 - Build Excel Data Set																
Task 3 - Additional Data Collection (If Required)																
Task 4 - Data Analysis / Calculations																
Task 5 - Write up case study																
Review period																
Key deliverables												Initial draft case study			Draft case study	

Legend

- Task progress
- Christmas holiday
- Review period
- Key deliverable

2.1.5 Data gaps and mitigation

During the development of the indicator a number of data gaps were identified which could impact the results. Where possible mitigation efforts were put in place to limit the impact on the calculations. To mitigate the gaps in the data available, proxy data, data interpolation, assumptions and extrapolation had to be made. The identified data gaps and mitigation strategies are included in Table 2-5 with an assessment in how effective they were.

[21] Mueller, Carina & de Baan, Laura & Koellner, Thomas. (2014). Comparing direct land use impacts on biodiversity of conventional and organic milk - Based on a Swedish case study. The International Journal of Life Cycle Assessment. 19. 10.1007/s11367-013-0638-5.

Table 2-5. Overview of identified data gaps, limitations and mitigation efforts

	Description of data gap	Mitigation efforts	Level of confidence
1	Food imports vs internal production.	• Assumption made that all food produced within country of consumption. During the data collection surveys no information was recorded on the origin of the food. This is discussed further in Section 2.2.2	Low
2	Levels of intensity of farming used in each country/ratio between different intensities.	• Calculations run looking at high, medium and low intensities. Although a mix of intensities is the reality. • Farming does not fall into neat categories of high, medium and low intensities and different practices will have a range of different effects on biodiversity	Low
3	Age of data all over 3 years old.	• As up to data used as possible given resources available from EFSA. • More recent data may however show a COVID-19 effect due to household habits changing during the pandemic (e.g. financial constraints of food, eating in more and supply chain constraints) so avoiding these years will give a more reliable indication of trends.	High
4	Some food types detailed in the study do not specify the ingredients used (e.g. canned meat without specifying the type of meat involved).	• Same assumptions made across all surveys/countries about which products to include (e.g. unspecified canned meat excluded). • In cases of uncertainty over if food source was part of the scope then it was discounted.	Medium
5	Limited number of participants in studies.	• Surveys selected with maximum scope for participants (surveys with restrictions not selected such as surveys focusing on children or pregnant women). • Surveys with most responses (that also met other criteria required) selected.	Medium
6	Data gaps across multiple European countries identified.	• Three countries were chosen to represent two contrasting states. This was also based on what data was available with survey data available from the following nations in the time period 2018 to present: Republic of North Macedonia, Italy, Hungary, Austria, Serbia and	High

	Description of data gap	Mitigation efforts	Level of confidence
		Romania. The time period 2018 to present was used to ensure up to date data.	

2.1.6 Quality review of analysis

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

- 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 addressed any comments from the review process, they proceeded to the data collection phase.
- Data being used in this project has already been validated pre-publication, however following calculations these were reviewed and validated by Ricardo's in house Quality Assurance Manager.
- The final data outputs and report has been reviewed by Hilke Schweer (Senior Catchment Management and Water Resources Consultant Consultant), Jose Ospina Giraldo (Circular Economy Principal Consultant) and Jess Twemlow (Project Director).

2.2 KEY ANALYSIS RESULTS

2.2.1 Analysis

The results showed that in Italy adults on average consumed more beef (43.31g per person per day) compared to adults in Romania (14.16 g per person per day) and adults in Hungary (10.34 g per person per day) and had a larger impact on biodiversity than households in the other two countries (Table 2-6).

Table 2-6: Comparison of the impacts of beef consumption per household for Romania, Italy and Hungary

Data Source	Potential mammal species lost per household from beef production (species per ha per year)		
	Low intensity	Moderate intensity	High intensity
Romania	1.15E-04	1.25E-04	1.10E-04
Italy	5.76E-04	6.23E-04	5.46E-04
Hungary	6.28E-05	6.84E-05	5.91E-05

The trend of food consumption in Italy having higher impacts on biodiversity per household was the same for their grain consumption, see Table 2-7. Even though the grain consumption per household was higher in Hungary than Italy, in Italy farming has a higher predicted species lost per m^2 than Hungary. This resulted in a greater impact on biodiversity per household.

Table 2-7 Comparison of the impacts of grain consumption per household for Romania, Italy and Hungary.

Data Source	Potential mammal species lost per household from grain production (species per ha per year)		
	Low intensity	Moderate intensity	High intensity
Romania	2.49E-07	2.80E-07	2.86E-07
Italy	5.06E-07	5.66E-07	5.76E-07
Hungary	2.49E-07	2.80E-07	2.86E-07

A comparison of the impacts of beef and grain consumption per household in Romania was carried out to assess how the different food products impacts varied within one country. As predicted, beef consumption had a much greater impact on biodiversity. This is in line with current prevailing opinion that reducing meat consumption/ promoting plant-based diets will be beneficial to preserving our natural environment. This result is consistent across the different levels of intensity of farming varying across the three countries assessed.

Table 2-8 Comparison of the impacts of beef and grain consumption per household for Romania

Food source	Potential mammal species lost per household from different food production in Romania (species per ha per year)		
	Low intensity	Moderate intensity	High intensity
Beef	1.15E-04	1.25E-04	1.10E-04
Grain	2.49E-07	2.80E-07	2.86E-07

These results indicate that the amount consumed as well as the country of origin both play a role in determining the impact per household on biodiversity. Higher levels of consumption results in greater impacts but also in some countries this impact is proportionally larger, this could be due to higher baseline biodiversity, greater variety in bioregions or farming practices in those countries.

Please view Appendix 4.1 for the detailed dataset developed and relevant calculations.

2.2.2 Limitations

The key limitations of the results are summarised here:

- Simplifications and assumptions required for the calculations affect the confidence level in the results. The data did not account for all the potential variabilities relating to food production such as imports vs home grown, regional variations in diet and production, levels of waste per product and details of food contents. Assuming all food is produced within the country ignores the global nation of the modern food supply chain. Many countries import a significant portion of their food, which means that the biodiversity impacts of consumption can be displaced to other regions. This global transfer of environmental impacts is not captured in the analysis.
- Reliance on survey data that is only collected sporadically with several years in between nations updating their surveys means it is hard to consistently compare impacts across the European Union.
- Despite good responses on the surveys with all having over 70% responses the data is limited by the number of interactions with Hungary with 529 responses, Italy with 726 responses and Romania with 740 responses. This is a very small representation of the population in the countries to draw conclusions from given the GDP per capita, population size and geographic variety of these nations (as discussed in Section 2.1.1.1). Although designed to be as representative as possible due to the number of variables present a larger representative survey would reduce the chance of
- The entire calculation relies on the calculations for “Potential species loss*years/m2” created by Chaudhary *et al.*. This limits any adaptability of the indicator as these calculations would require a large investment of time to recreate and update/edit.
- There are considerable limitations on the resolution of data at a country-level. There are likely to be regional differences within each country, for example beef consumption may be higher in higher income households as indicated by the higher consumption in grams per person for Italy than the other two nations with Italy having a higher GDP per capita.
- The data points are based on self-reported food consumption, which can be subject to recall bias or inaccuracies in portion size estimation.
- A wide range of socio-economic factors may drive consumption patterns and their impacts on biodiversity affect the results. Factors such as income levels and cultural practices will play a role, in determining consumption and will vary within countries as well as between countries.
- Farming practices cover a wide spectrum of impacts and as such do not fall neatly into low, moderate and high-intensity classifications. As such a lot of detail and variation can be lost in grouping farming into such wide bands.

2.2.3 Performance

Table 2-9 displays the results of the RACER evaluation. The biodiversity indicator is ranked highly for relevance with widespread awareness of the issues with biodiversity loss. The indicator is highly relevant to the circular economy due food needing to be a renewable resource. Due to the limitations discussed above, the credibility, ease and robustness are ranked low resulting in a lower performance than predicted.

Ease and robustness were downgraded following completion of the testing. As discussed above the simplifications and assumptions made reduce the robustness of the Task. In order to reduce the number and magnitude of assumptions made when running the data further steps will be required in the data collection stage which is why the ease score has been reduced. The further steps would require gathering data on the source of each food product consumed and the production method. These are details which the consumer is unlikely to know.

Table 2-9. RACER evaluation

Stage of project	RACER criterion					Score
	Relevance	Acceptability	Credibility	Ease	Robustness	
Task 4 (original RACER assessment)	3	3	2	2	2	12
After Task 5 (following testing)	3	3	2	1	1	10

To ensure consistency in applying RACER, the assessment matrix shown in Appendix 4.2 was applied to support the decision making process.

2.3 CHALLENGES AND LESSONS LEARNED

2.3.1 Challenges

There were multiple challenges faced during the development of this indicator. These mostly related to the wide range of factors that could impact the results of the indicator and the data available, including:

- Working with the data available at the time meant there was detail on the different foods consumed but additional data relating to the production methodology, location of food production was missing. Due to this a lot of assumptions had to be made in order to produce a final output which will affect the accuracy and reliability.
- As discussed in the limitations the current analysis does not consider the global supply chain of food and how many countries import/export a large amount of certain foods. When considering the impacts of food consumption in each country it will be important factor in where the food is produced. As shown production can have a varying impact depending on where and how it is produced. To truly assess the household impact these details will need to be factored in.
- As well as the impact at a national level with food imports / exports there is also likely to be large regional variation across many countries. As an example, there is likely to be a large variation in food types and their amounts consumed between northern France and southern France. This regional level variation is not captured in the model and is also a lot of variation to capture in a survey.
- The collection of data on food consumption for the EU countries varies from country to country with some collecting data regularly (Austria carried out a 24-hours dietary recall survey every other year from 2010 – 2018) and others more infrequently with no survey data from Belgium since 2007 for example.
- There is also variability in the data collection methodology with different approaches to sampling stratification across countries. Some countries focus more on achieving a geographical spread

(Italy[22]), a socio-economical spread (Hungary[23]) and others an age spread (Slovenia[24]). There is also variability in the questionnaire methodology and analysis software. These surveys are designed to allow comparison with previous surveys within the same country (such as in Finland with surveys predating the EU[25]) rather than cross border comparison.

2.3.2 Lessons learned

Lessons learnt were recorded through the process of creating this indicator. These may be applied to inform future assessments of household impacts on biodiversity, including:

- The issues with the data collection process as set out above and the requirements for additional details mean that any future analysis of this indicator would require a bespoke survey in order to gather the required information and ensure consistency across the different states within the EU.
- Greater levels of data would need to be gathered during the survey process for this indicator to provide reliable information. This would require changes to the EFSA Menu methodology[26] to ensure the required information is collected across the different member states surveys.

[22] CREA-Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria - Centro di Ricerca Alimenti e Nutrizione. Turrini A., Le Donne C., Piccinelli R., D'Addezio L., Mistura L., Sette S., Martone D., Comendador Azcarraga F.J., Ferrari M., Catasta G., 2022. Italian national dietary survey on adult population from 10 up to 74 years old – IV SCAI ADULT. EFSA Supporting Publication 2022: 19(9):EN-7559. 39 pp. doi:10.2903/sp.efsa.2022.EN-7559

[23] National Food Chain Safety Office, Hungary, Csizmadia K, Larnsak L., Pfaff N., Sali J., 2020. Hungarian national food consumption survey on adults. EFSA supporting publication2020: 17(12):EN-1981. 26 pp. doi: 10.2903/sp.efsa.2020.EN-1981

[24] National Institute of Public Health. Gregorič M, Blaznik U, Delfar N, Zaletel M, Lavtar D, Koroušić Seljak B, Golja P, Zdešar Kotnik K, Pravst I, Fidler Mis N, Kostanjevec S, Pajnkihar M, Poklar Vatovec T, Hočevar Grom A, 2019. Slovenian national food consumption survey in adolescents, adults and elderly. EFSA supporting publication 2019:EN-1729. 28 pp. doi:10.2903/sp.efsa.2019.EN-1729

[25] Finnish Institute for Health and Welfare, Kaartinen N, Tapanainen H, Reinivuo H, Pakkala H, Aalto S, Raulio S, Männistö S, Korhonen T, Virtanen S, Borodulin K, Koskinen S and Valsta L, 2020. The Finnish National Dietary Survey in Adults and Elderly (FinDiet 2017). EFSA supporting publication 2020:EN-1914. 26 pp. doi: 10.2903/sp.efsa.2020.EN-1914

[26] European Food Safety Authority, 2014. Guidance on the EU Menu methodology. EFSA Journal 2014; 12(12):3944, 77 pp. doi:10.2903/j.efsa.2014.3944

2.4 CONCLUSIONS AND RECOMMENDATIONS

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

Due to the comprehensive data requirements required to accurately measure the household level impacts on biodiversity, advancing this indicator is likely to be feasible, but work is needed. To enable a reliable output from this indicator it would require greater detail in the following areas:

- Is the food grown locally or imported?
- If imported, where is it imported from?
- What levels of intensity is the food produced under?
- Is there seasonal variation in food consumed?

This level of detail, particularly regarding farming practices, is often beyond what consumers might know. Examining biodiversity impacts would likely be better studied at a higher level such as city/region rather than at household level. At a higher level, there will likely be more detailed and comprehensive data relevant to the points raised above. To investigate this further, additional research should be carried into the best possible sources and routes to access the types of data listed above. This could identify key stakeholders who could then be engaged with to discus and collaboratively develop adequate processes and tools for data collection and reporting. Recommendations are summarised in Table 2-10.

Following the testing of this indicator, the initial indicator name is still deemed fit for purpose to take forward. However, if the scope of the indicator is refined this could be reviewed.

Table 2-10: Summary of recommendations for indicator 2

Type of recommendation	Recommendation	Timeline	Key stakeholders or partners	RACER Criteria addressed
R&D	Adapt biodiversity indicator to a Cites and Regions level, and in this light, investigate best routes and stakeholders to engage with to provide further detail such as: • Is the food grown locally or imported? • If imported, where is it imported from? • What levels of intensity is the food produced under? • Is there seasonal variation in food consumed?	Medium (1.5 – 5 years)	European Commission	• **Relevance:** The indicator will provide better insight if looked at a smaller geographical scope to pick up changes between regions which may be lost at a national level. • **Robustness:** With the extra detail discussed, a more complete and robust methodology could be developed.
Stakeholder engagement	Following from the above, engage with identified stakeholders to investigate data needs, challenges to collection and reporting, and potential mitigations to those challenges.	Long (> 5 years)	European Commission	• **Acceptability:** Collaborative engagement with identified stakeholders, and joint development of solutions to challenges, will develop buy-in. • **Ease:** Identifying the further steps to be taken at this stage will lay the groundwork for smooth data reporting and collection in the future.
R & D	Update the EFSA Menu methodology to ensure more regular surveys across all Member States	Long (> 5 years)	EFSA and national institutes for each member state	• **Robustness:** Would allow for more comprehensive data and greater comparison between states. • **Ease:** Would allow for easier data comparison and updating of results to reflect changes.

3. INDICATOR 2: 'WATER FOOTPRINT OF PRIVATE CONSUMPTION, AT NATIONAL LEVEL'.

This indicator focuses on the water footprint of private consumption at a household level on a national scale. The water footprint measures the amount of water used to produce each of the goods and services people use. It can also be defined as the everyday household use of water from both direct sources and indirect sources.

This is of significant relevance to the circular economy (CE) because fresh water is the highest used natural resource among many products consumed daily such as food, clothing and electronics (Sandu & Vîrsta, 2021). Assessing the water footprint of products and services and gaining a baseline is a valuable step towards the evaluation of the CE of water. In order to align with the CE, the water footprint assessment must outline what happens to water after its use and how circular it is.

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

- It enables the EU to identify the areas of high consumption of water by households.
- Identifying areas of water dependence in a particular operation, supply chain, or nation(s).
- Identifying uses, industries or products where water can be reduced or recycled.
- It helps improve understanding of what purposes limited freshwater resources are being consumed for.

This case study sets out the methodology, data collection, results, limitations and challenges, and conclusions to assess the household water footprint at a national level.

3.1 KEY METHODOLOGY

3.1.1 Testing method

3.1.1.1 Spatial scope

Due to transnational variations within the European Union (EU) member states based on GDP, consumption, and infrastructure, two member states were chosen which were assumed to be different in their water consumption. These were Bulgaria and the Netherlands. It was assumed that their water consumption was likely to be typically different due to large variations in GDP per capita and general consumption levels between the countries. The data was collected on a national scale, meaning regional differences (such as urban/rural consumption) within the individual countries were accounted for.

3.1.1.2 Temporal scope

Two separate years' worth of data were included in testing of this indicator based on the availability of data. All data between 2015 – 2023 used to calculate the water footprint was scoped initially. Following this exercise, it became apparent that 2019 and 2020 had more data available compared to the other years (between 2015 – 2018) for both countries. Therefore, this indicator only used data from 2019 and 2020 with both years' results being compared within the report. This allowed for temporal variations to be shown within the data.

3.1.1.3 Data scope

The water footprint indicator was focused on the private consumption of water by the household. This was defined as the everyday household use of water from both direct sources and indirect sources.

- Direct sources of water use included the water used inside the household from water mains (e.g. taps, hosepipes, toilet, shower, washing machines, dishwashers, etc.). This included both public and private water supply data.
- Indirect sources of water use included water used to create products and services consumed. Five indirect source categories were chosen to be used in this indicator: the water footprints of food, transport, electricity and clothing. Other indirect sources such as other household products and services (e.g. furniture and electronic devices) consumed by individuals were not included. Due to time and resource limitation the five categories were selected as they represent some of the largest

water consumers based on available data. The overall footprint was therefore a rough estimate including some of the largest inputs to water footprint of households.

- Water imports and exports, through direct sources such as transfer of freshwater from one country to another, or indirectly through consumer products and services. Due to its complexity, this source was omitted from water footprint calculations.

This indicator included the footprint of renewable freshwater resources only, such as rainwater, groundwater, aquifers, and surface water (lakes and rivers). This means that desalinated sea water and recycled water are not included.

3.1.2 Data collection method

A summary of data collected can be seen in Table 3-1.

Social and economic data surrounding the water footprint indicator was predominantly sourced and retrieved from Eurostat (the statistical office of the EU that hosts European-wide statistics for a wide range of indicators). Due to high data availability within Eurostat, additional indirect sources of water footprint to those discussed within the data collection plan were also included (i.e., electricity and transport). Specifically, data was sourced from three of their statistical indicator branches:

- Economy and finance.
- Population and social conditions.
- Environment and energy.

To support the social and economic data retrieved, water consumption and water footprint statistics were collected from reliable sources, such as the Water Footprint Network and the World Wide Fund for Nature (WWF), that provide numerous academic literature such as global meta-analyses and life cycle analyses (LCA) to support their data.

Once retrieved, all data was screened to determine if sufficient evidence had been collected to form robust calculations for water footprint. Where gaps were identified, additional data sourcing was undertaken to find the information needed. To complete this, a variety of other sources were utilised including statistics websites (The Global Economy) and academic literature.

Table 3-1. List of data sources for 2019 and 2020

#	Source	Data collected	Reliability*	Availability**
1	Eurostat	• Annual total population on 1st January • Average household size and number of persons • Annual total water supply usage by households (public and private) • Electricity consumption in households (thousand tonnes of oil equivalent) • Oil and petroleum consumption by transport sector (road, rail, and domestic aviation) • Clothing consumption expenditure of all households	High	High
2	WWF's "How does what you eat affect the planet?"[27]	Typical diets of countries by WWF	Low	Medium
3	Water Footprint Calculator[28]	• The water footprint of food guide • Water footprint of gasoline production, car manufacturing and clothing per unit	Medium	High
4	The Global Economy[29]	• Annual passenger car new sales/registrations (Total)	Medium	Medium
5	Numbeo – Cost of Living Database[30]	• Average cost per clothing unit	Low	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.*

[27] WWF, How does what you eat affect the planet?, https://planetbaseddiets.panda.org/impacts-action-calculator, [Accessed February 2024]
[28] Water Footprint Calculator, https://watercalculator.org/, [Accessed February 2024]
[29] The Global Economy, https://www.theglobaleconomy.com/, [Accessed February 2024]
[30] Numbeo, Cost of Living, https://www.numbeo.com/cost-of-living/, [Accessed February 2024]

3.1.3 Calculations

Prior to the final calculations of household water footprint for Bulgaria and the Netherlands, household population data, household direct water and indirect water usage figures (*as explained in Section 2.1.1.3 Data Scope*) were estimated. The data calculations required were:

- Population (household level).
- Direct household water usage:
  - Consumption from water mains (e.g. taps).
- Indirect household water usage:
  - Food consumption.
  - Electricity consumption.
  - Transportation consumption.
  - Clothing consumption.

All water footprint calculations were converted and expressed as cubic metres per year (m^3 y^{-1}).

3.1.3.1 Population

In order to assist with calculations of water footprint per household, the total number of households within the Netherlands and Bulgaria were calculated. Data sources used for these calculations can be seen in Table 3-2.

Table 3-2. Data sources to calculate total number of households

Metric	Source
Annual total population on 1st January	Home - Eurostat (europa.eu)
Average household size	Home - Eurostat (europa.eu)

The following calculation was used:

$$\boldsymbol{Total\ \#\ of\ households} = \frac{Population\ on\ 1st\ January}{Average\ Household\ Size}$$

Based on the calculations above, the total number of people per household was 2.4 for Bulgaria (in both 2019 and 2020) and 2.1 for Netherlands (in both 2019 and 2020). These figures were then used for the rest of the calculations.

3.1.3.2 Direct Household Water Usage

The annual direct household water usage was calculated using the data sources seen in Table 3-3.

Table 3-3. Data sources to calculate direct household water usage

Metric	Source
Annual total public water supply usage by households	Home - Eurostat (europa.eu)
Annual total private water supply usage by households	Home - Eurostat (europa.eu)
Total number of households	Calculated using data sources in Table 3-3.

The following calculation was used:

$$\textit{Annual direct household water usage} = \frac{D_1 + D_2}{Total\ \#\ of\ households}$$

$D_1 = \textit{Annual total public water supply usage by households}$
$D_2 = \textit{Annual total private water supply usage by households}$

3.1.3.3 Water Usage from Food

The water usage relating to food was calculated using a breakdown of typical diets by country, alongside average water footprints for specific food groups (see Table 3-4).

Table 3-4. Data sources to calculate household water usage from food consumption

Metric	Source
Typical diets of countries by WWF	How does what you eat affect the planet? (panda.org)
Water footprint of food guide	Water Footprint of Food Guide - Water Footprint Calculator (watercalculator.org)
Average number of persons in the household	Home - Eurostat (europa.eu)

The lists of foods provided by the 'Water Footprint of food guide', and their corresponding water footprints, were categorised into the following food groups:

- Alcohol
- Eggs
- Fruits and Vegetables
- Red Meat
- Sugar
- Coffee, Tea and Cocoa
- Fats and Oils
- Grains
- Roots and Tubers
- Dairy
- Fish
- Legumes, Nuts and Seeds
- Poultry

Average water footprints were then calculated for each food group based on categorisation of the individual foods. Total water usage per household from food was calculated as followed:

$$\textit{Water usage per household from food} = SUM(F_1 * F_2) * Average\ household\ size$$

$F_1 = \textit{Food group servings per person per year}$
$F_2 = \textit{Food group water footprint per serving}$

3.1.3.4 Water Usage from Electricity Consumption

The water footprint relating to household electricity consumption was calculated using the following data sources in Table 3-5.

Table 3-5. Data sources to calculate household water usage from electricity consumption

Metric	Source
Electricity consumption in households (thousand tonnes of oil equivalent)	Home – Eurostat (europa.eu)
Total number of households	Calculated using data sources in Table 3-2.
Water footprint of gasoline production	Energy Production and the Water Footprint of Energy (watercalculator.org)

Electricity consumption from the Eurostat dataset is reported in units of thousand tonnes of oil equivalent. To calculate water footprint related to electricity consumption, an assumption was made that the '*oil equivalents*' that the electricity consumed was provided as related to gasoline production. This assumption allowed for a simplification of the calculation as data on the average water footprint of gasoline production was widely available from the Water Calculator data source (Table 3-5). A value of 4.75 m^3 of water to produce one m^3 of gasoline (m^3/m^3) was used for the average water footprint of gasoline.

The following calculation was used:

$$\textbf{Water usage relating to electricity consumption per household} = \frac{H_1 * H_2}{Total\ \#\ of\ households}$$

H_1 = *Electricity consumption in households (oil equivalents)*
H_2 = *Average Water footprint of gasoline production*

3.1.3.5 Water Usage from Transportation

To calculate the total water footprint from household transport, multiple sources were included relating to car sales and fuel consumption for road, rail and aviation transport (see Table 3-6).

Table 3-6. Data sources to calculate household water usage relating to transportation

Metric	Source
Annual passenger car new sales/registrations (Total)	Bulgaria Passenger car sales - data, chart | TheGlobalEconomy.com Netherlands Passenger car sales - data, chart | TheGlobalEconomy.com
Total number of households	Calculated using data sources in Table 3-2
Water footprint of car manufacturing	The Hidden Water in Everyday Products - Water Footprint Calculator (watercalculator.org)
Oil and petroleum consumption by transport sector (road)	Home - Eurostat (europa.eu)
Oil and petroleum consumption by transport sector (rail)	Home - Eurostat (europa.eu)
Oil and petroleum consumption by transport sector (domestic aviation)	Home - Eurostat (europa.eu)
Water footprint of gasoline production	Energy Production and the Water Footprint of Energy (watercalculator.org)

To carry out the calculations, the following assumptions were required:

- Statistics relating to petroleum consumption by transport sector includes all travel, not just by households. For the purpose of this calculation, it was assumed to be only relating to household use.
- For simplicity within calculations, oil and petroleum consumption were assumed to only relate to the use of gasoline.
- An average water footprint of car manufacturing of 67.5 m^3 was assumed.
- An average water footprint of gasoline of 4.75 m^3/m^3 was assumed.

The following calculations were used:

$$\textbf{Water usage from car sales/registrations per household} = \left(\frac{T_1}{Total\ \#\ of\ households}\right) * T_2$$

$$\textbf{Water usage from petroleum consumption (Transport)} = \left(\frac{T_3 + T_4 + T_5}{Total\ \#\ of\ households}\right) * T_6$$

T_1 = *Passenger car total new sales/registrations*
T_2 = *Average water footprint of car manufacturing*
T_3 = *Oil and petroleum consumption by road*
T_4 = *Oil and petroleum consumption by domestic aviation*
T_5 = *Oil and petroleum consumption by rail*
T_6 = *Average water footprint of gasoline production*

3.1.3.6 Water Usage from Clothing

The water usage relating to clothing consumption was calculated using a breakdown of household clothing expenditure, average prices of clothing units per nation, and the average water footprints of specified clothing units (see Table 3-7).

Table 3-7. Data sources to calculate household water usage relating to clothing

Metric	Source
Total number of households	Calculated using data sources in Table 3-2
Clothing consumption expenditure of all households	Home - Eurostat (europa.eu)
Water footprint of clothing per unit	The Hidden Water in Everyday Products - Water Footprint Calculator (watercalculator.org)
Average cost per clothing unit	Cost of Living (numbeo.com)

In order to do this, a couple of assumptions were required:

- For simplicity within calculations, clothing consumption was assumed to only relate to a 'typical' range of clothing. In this case, jeans, cotton t-shirt (or dress) and leather shoes were chosen. This was due to data availability and to represent a wide range of water usage for a more realistic footprint. An average of these three items was calculated to create (1) an average cost per clothing unit, and (2) an average water consumption per clothing unit.
- Due to a lack of data on overall water consumption from clothing (textiles, leather, etc.) from Eurostat, other data sources were used which may not be as reliable.

The following calculation was used:

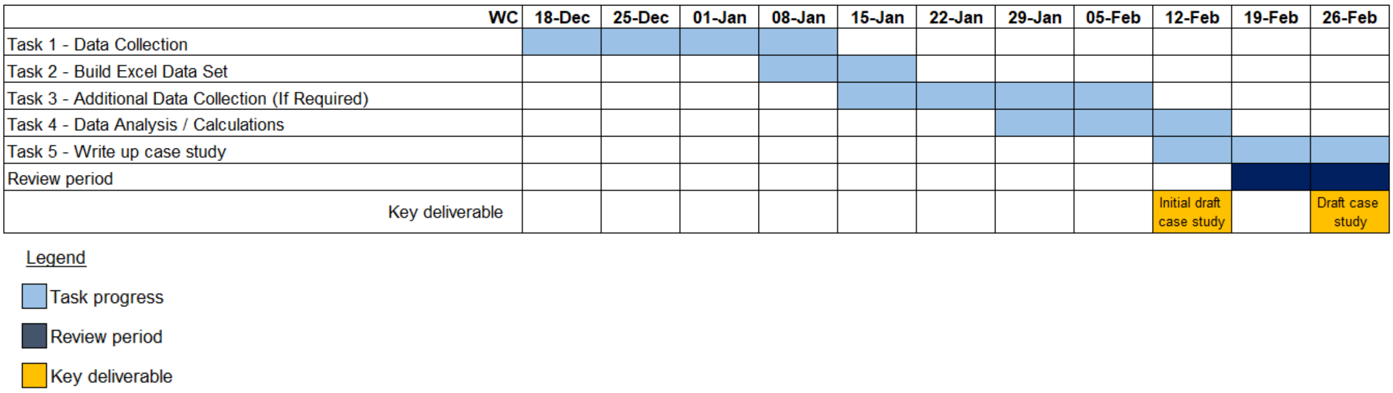
$$\textbf{Water usage relating to textiles consumption per household} = \frac{\left(\left(\frac{X_1}{X_2}\right) * X_3\right)}{Total\ \#\ of\ households}$$

X_1 = *Final clothing consumption expenditure of all households*
X_2 = *Average cost per clothing unit*
X_3 = *Average water consumption per clothing unit*

3.1.4 Timeline

The project timeline for the water footprint indicator is shown in Table 3-8.

Table 3-8. Gantt chart



3.1.5 Data gaps and mitigation

The identified data gaps and mitigation strategies are included in Table 3-9. Due to gaps in the available data, proxy data, data interpolation and extrapolation, alternative data sets were sourced and incorporated into the indicator data were appropriate.

Table 3-9. Overview of identified data gaps, limitations and mitigation efforts

	Description of data gap	Mitigation efforts	Level of confidence
1	Did not account for electricity generation methods for Bulgaria and Netherlands when calculating water usage from electricity consumption.	• Additional metrics were collected surrounding electricity generation by type and the water footprint relating to these types. • Additional calculations were performed to attempt to account for this. It was felt that these calculations greatly overcomplicating the method and thus a simpler method more consistent with other water usages within this report section was deemed to be more appropriate.	Medium
2	Temporal data gaps due to a lack of data in between 2021 – 2023 across multiple data sources.	• Decided to use 2019 and 2020 data to create two comparative years' worth of results and to ensure consistency in our approach. • This may however show a COVID effect due to household habits changing during the pandemic (e.g. lower transportation needs and/or higher household direct public water supply).	High
3	Lack of data on water footprint of food at a household level per nation. WWF provide a figure for water footprint per person per nation based on a 'typical' diet,	• Used the WWF data for a 'typical' diet for each nation and used an alternative method to calculate the footprint (see Table 3-4).	Medium

	Description of data gap	Mitigation efforts	Level of confidence
	however this data was not robust enough for this assessment due to a lack of information on the units of water use.	• Used data on water footprint per food group to calculate the use per capita within each nation.	
4	No raw data available from Eurostat on the water consumption for textile and clothing production per nation.	• Alternative sources of data were found to create an estimated calculation of water footprint per household from clothing (see Table 3-7).	Low
5	Data gaps across multiple European countries identified.	• Two countries were chosen to represent two contrasting states. This was also based on what data was available. Sweden, Netherlands, Poland, Croatia and Bulgaria were the countries with the most data available on Eurostat, while Iceland, Hungary and Luxembourg had the least data available.	Medium
6	Exclusion of water imports and exports	• Additional time spent attempting to source relevant data and develop a methodology to factor in global trade. However, this was eventually deemed too complex to incorporate. • Water imports and exports were decided to be excluded from the water footprint calculator based on the fact imported goods were already included in other data sources by directly looking at household consumption.	Medium
7	Source used for prices of textile goods lacking in accuracy due to community-led statistics and not accounting for temporal changes in prices.	• A more robust data set for prices of goods was recommended, such as the consumer price index basket of 2019 and 2020. • Due to difficulties sourcing this information, and textiles accounting for only a small fraction of water footprint, no amendments were made. Additional sources were added to the final recommendations.	Medium

3.1.6 Quality review of analysis

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

- Prior to work beginning, the Project Director (Jess Twemlow) reviewed the proposed research methodology and ensured that the data collection plan was fit for purpose. Once the research team addressed any comments from the review process, they proceeded to the data collection phase.
- Data being used in this project has already been validated pre-publication, however following calculations these were reviewed and validated by Hilke Schweer (Senior Catchment Management and Water Resources Consultant Consultant).
- The final data outputs and report has been reviewed by Hilke Schweer (Senior Catchment Management and Water Resources Consultant Consultant) and Jess Twemlow (Project Director).

3.2 KEY RESULTS

The following sub-headings present the key results from the testing of this indicator.

3.2.1 Analysis

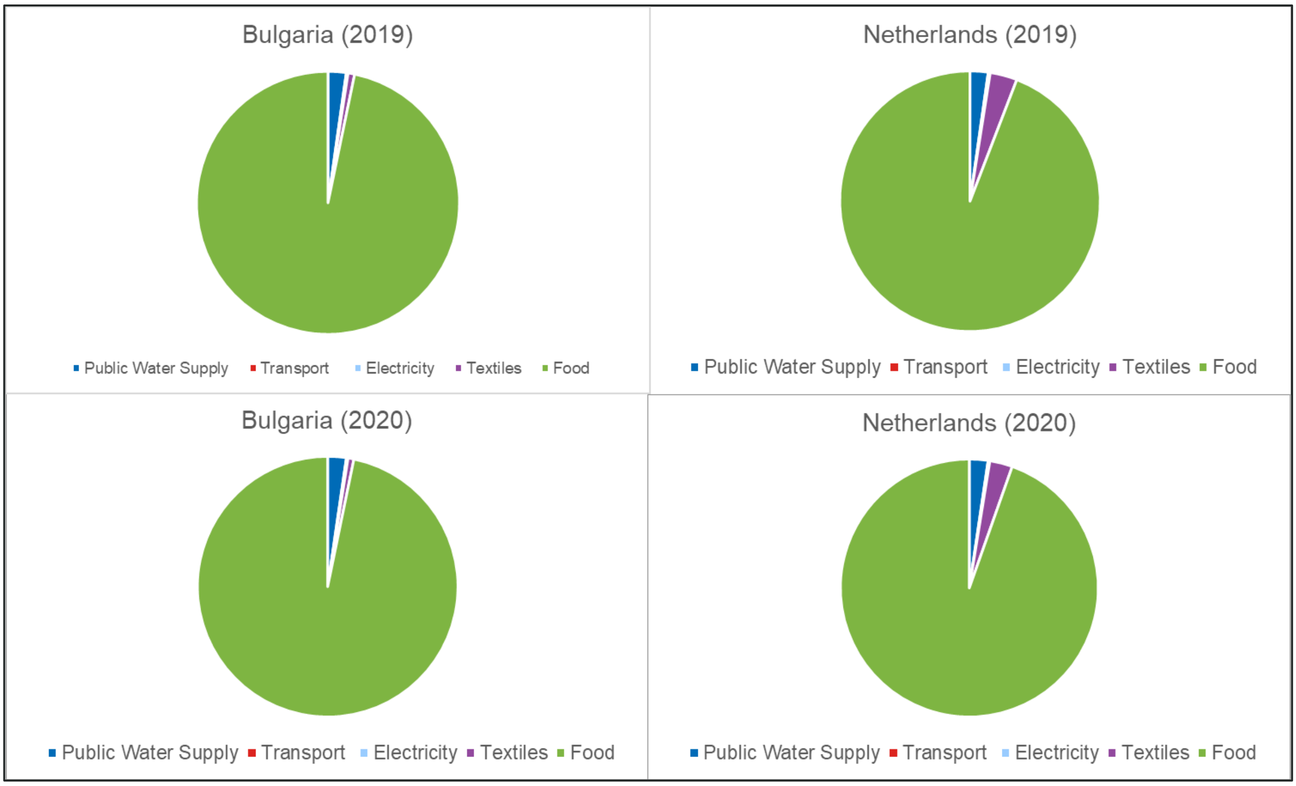
A breakdown of household water footprint for both the Netherlands and Bulgaria, for the selected direct and indirect sources of water use, can be seen in Table 3-10.

Table 3-10. Water footprint per household in 2019 and 2020 for Bulgaria and the Netherlands

Water Footprint per household ($m^3\ y^{-1}$)				
	2019		2020	
Water categories	**Bulgaria**	**Netherlands**	**Bulgaria**	**Netherlands**
Public Water Supply	86	102	89	106
Transport	7	10	6	9
Electricity	2	1	2	1
Textiles	31	149	28	126
Food	3,731	4,174	3,731	4,174
Total	**3,857**	**4,434**	**3,856**	**4,412**

It can be seen from these calculations that water usage relating to the production of food is the largest contributor to water footprints of households, accounting for over 95% of the total water footprint (Figure 3-1). In both 2019 and 2020, the water footprint of households in the Netherlands was considerably higher at 4,434 $m^3\ y^{-1}$ in 2019 and 4,412 $m^3\ y^{-1}$ in 2020. Bulgaria had a lower water footprint with 3,857 $m^3\ y^{-1}$ reported in 2019 and 3,856 $m^3\ y^{-1}$ in 2020. In 2019, this equated to a 15% higher water footprint for Netherlands, compared with 14% in 2020. The main contributor to this larger footprint was due to the increased water usage from diet, with slightly increased water usages also relating to higher public water supply and increased transport water usage. For both countries, negligible differences in the water footprint between 2019 and 2020 was observed. However, it is uncertain whether this correlates to a lack of difference or a factor of the method used. Due to data availability, no temporal variations in typical diets for Bulgaria and the Netherlands could be accounted for when calculating water footprint from food, resulting in equivalent water footprints relating to food for both 2019 and 2020. With food being the main contributor, this makes temporal trends difficult to observe.

Figure 3-1. Breakdown of water footprint by type



Please view Appendix 4.3 for the detailed dataset developed and relevant calculations.

3.2.2 Limitations

The key limitations to the results are summarised below:

- Due to the missing data sources highlighted in Table 3-9, multiple assumptions have been made, with not all inputs to a water footprint being included in the data set. This means that the reported results are likely to be lower values compared with an all-inclusive water footprint.
- The data presented is not the most up-to-date, as data from 2019 and 2020 was applied due it is completeness and reliability. 2022 and 2023 data may show more robust results if data availability is improved throughout the years. In addition, this lack of data completeness for some years make temporal trends difficult to observe (e.g.: Data of car purchases of Bulgaria and Netherlands in 2019 and 2020 does not show the increasing trend of car purchases in Bulgaria over the years)
- Some of the data sources used may overestimate water usage. For example, statistics relating to petroleum consumption by transport sector includes all travel (not just by households) and therefore may overestimate household consumption when water usage was calculated.
- Simplifications were made regarding the electricity water usage calculations. For example, it was assumed that "oil and petroleum equivalents" related to gasoline. The data also did not account for variances in energy production technologies (e.g. gas, coal, wind, solar, etc.) which will each have varying water usages to produce electricity. This also may affect the granularity of the data and reduce its accuracy.
- With over 95% of our water usage coming from food, the limitations surrounding this data source are of greater weighting than the other components of the water footprint calculation. Therefore, any limitations or inaccuracies within the food water usage calculations are likely to have a much greater impact on the overall indicators' accuracy than the other components.
- There is no annual data on a "typical diet" for food water usage calculations, thus making trends difficult to observe. The food water footprint was calculated based on food groups rather than individual products from a typical diet, meaning the granularity of the data is affected and may be less accurate. With food consumption being such a heavily weighted component of water usage by households

another data source is recommended to be used in future, such as household food expenditures or scientific literature relating to the water footprints of different diets.

- Data included the water footprint of the indirect consumption of water through imports. For example, with food consumption data, it is assumed that a proportion of the food consumed by a nation is not produced within the consuming nation, meaning the indirect water footprint was able to be included in this calculation.
- There are likely to be some issues with accuracy of the public water supply (direct household water use through taps, etc.). Due to the lack of metered water data, the water consumption lacks granularity as the data does not account for any illegally abstracted water, or water loss during treatment (e.g.: leakages). It may therefore be over or underestimated in the results as some sources of supply may not be reported to the state or supply may account for water loss not directly related to household usage.
- There are considerable limitations on the granularity of data at a national-level. There are likely to be regional differences within each nation, for example water consumption may be higher in rural areas compared to cities and may be higher in higher income households.
- The source highlighting the average prices of textile goods in Bulgaria and Netherlands has community driven statistics, which could result in errors. In addition, these values only account for the current 2024 prices of textile goods, making temporal changes in prices (such as due to inflation) difficult to account for.

3.2.3 Performance

Table 3-11 displays the results of the RACER evaluation. The water footprint indicator is ranked highly for 'relevance' and 'acceptability' due to the concept of a water footprint being widely used and recognised universally. It is highly relevant to the CE due to water being part of the water cycle as a renewable resource. Due to the limitations discussed above, 'credibility', 'ease' and 'robustness' are ranked lower. Following the testing stage, the RACER "Ease" criterion was reduced. Initially it was assumed that all data required would be accessible through various statistical data sources, for the different components outlined for the water footprint of household's calculation within the data collection method (Section 3.1.2). During the testing phase it became apparent that much of the data required (especially surrounding water usage from food) either was not readily available, or not reliable enough to be used for calculations. Therefore, the RACER evaluation was reduced from 12 to 11.

Table 3-11. RACER evaluation

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

To ensure consistency in applying RACER, the assessment matrix shown in Appendix 4.2 was applied to support the decision-making process.

3.3 CHALLENGES AND LESSONS LEARNED

3.3.1 Challenges

There were multiple challenges faced during the monitoring process. These were addressed throughout the process and mitigations were made where possible. The key challenges were encountered when collecting data due to the data gaps discussed in Section 3.1.5. They were as follows:

- Finding the right balance of simplicity versus accuracy with the data set was difficult. The more accurately each water footprint input was calculated, the more complicated and difficult the methodology and testing became. The project resources and timelines restricted the accuracy of the methodology, so not all of the potential sources of household water footprint were able to be included in this indicator.

- There are other resources for calculating a water footprint such as the Water Footprint Network, which were not included within the developed water footprint indicator. This data set includes many more parameters such as other household items (e.g. furniture, cleaning products, electrical items, white goods, homeware, building materials, etc). Therefore, if this indicator is to be implemented in the future, is it recommended that these inputs be included to increase the overall robustness and accuracy of this calculation.
- Grey water is defined as the water polluted by the production of goods and services, with black water being specifically related to sewage wastewater generated by domestic activities. This accounts for 11% of the global water footprint and thus might have a significant impact on the national-level water footprint as discussed in this assessment[31]. In many countries black water is commonly treated and recycled within the public water supply system, through wastewater treatment plants and drinking water treatment facilities. As such the water footprint conducted within this study does not account for the impact recycling water has on reducing the demand for freshwater resources, and the variances in individual nations ability to treat grey and black water through water infrastructure.
- As a result of COVID-19 and the subsequent national lockdowns, individuals may have changed their typical behaviours and habits relating to the consumption of water within private household. As 2020 data was used due to a lack of recent data between 2021 – 2023, the results may be slightly skewed due to the exceptional year of household habits.

3.3.2 Lessons learned

Lessons learnt were recorded throughout the process of creating and testing this indicator, which may be applied to inform future assessments of water footprints on a national-level. They were as follows:

- The data highlighted that there are many further inputs (i.e. household items) to the water footprint which could be included in future assessments. It is recommended that initial scoping of what inputs are reasonable to include should be completed at the early state of the methodology plan. During this testing programme, this was mostly completed after identifying the data gaps/temporal gaps. The European Commission should aim to include more of these inputs by identifying and filling data gaps through supporting activities each year.
- During the data collection phase, it may have been beneficial to complete the calculations throughout the data gathering phase. This would have helped to see issues and gaps in data at an earlier phase, as many of the limitations with data sets and data gaps were identified at the calculation stage, thus hindering efficiency.

[31] The World Counts, 2024, https://www.theworldcounts.com/challenges/planet-earth/freshwater/global-water-footprint, Accessed 15/03/2024

3.4 CONCLUSIONS AND RECOMMENDATIONS

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

The water footprint indicator at household level is of significant relevance to the CE due to the catastrophic environmental damage unsustainable water consumption has on the world. Assessing the water footprint of products and services is a good step towards the evaluation of water circularity. The water footprint assessment must be integrated into the concepts of the CE by insisting on what happens to water after use and how circular and sustainable it is.

In this assessment, household water footprint in the Netherlands and Bulgaria was estimated on a national-level. The key findings from the results are that water usage relating to the production of food is the largest contributor to water footprints for households, accounting for over 95% of the total water footprint In both 2019 and 2020 water footprint by households in the Netherlands was considerably higher at 4,434 m^3 y^{-1} in 2019 and 4,412 m^3 y^{-1} in 2020. Bulgaria had a lower water footprint with 3,857 m^3 y^{-1} reported in 2019 and 3,856 m^3 y^{-1} in 2020. The main contributor to this greater footprint is related to the **increased water usage from diet**, with slightly increased water usages also relating to higher public water supply and increased transport. Negligible differences in water footprint between 2019 and 2020 was observed. Due to a lack of data, **no variations in typical diets** for Bulgaria and the Netherlands could be accounted for when calculating water footprint from food, resulting in identical water footprints for both 2019 and 2020. As food is the main contributor, this makes significant temporal trends difficult to observe.

With over 95% of the water usage metric coming from food, the limitations surrounding this component are of greater weighting than the other metrics. Therefore, any limitations, or inaccuracies within the food water usage calculations are likely to have a much greater impact on the overall indicator's accuracy than the other components.

There are few synergies between this indicator and the current EU monitoring framework. There are currently no indicators which focus on the circularity of water consumption, despite there being indicators on material footprint and consumption footprint. As water consumption is required to generate most material goods and services, it may be beneficial to develop a water-specific indicator to measure and inform circularity improvements and subsequent sustainability of global water usage.

A water footprint indicator would complement the new EU monitoring framework by supporting the indicators of global sustainability from CE. This will be done by developing the collection of data on water footprints across the EU to identify the circular material and consumption rate indicators. In addition, if water recycled by wastewater treatment was added into the indicator it would complement other household-based indicators currently within the waste generation monitoring framework. This new indicator has the potential to be a highly relevant and direct indicator of CE across the EU. However, the indicator requires significant further development in data availability and methodology in order to be robust. This could be achieved through potential new legislation, incentives and the research and development of data (as highlighted in Table 3-12). These recommendations will also improve the reliability, objectiveness, replicability and availability of the indicator across the EU member states.

Water resources in the EU are protected through various regulations including the Water Framework Directive (WFD)[32], Drinking Water Directive[33], and the Water Reuse Regulation[34]. These regulations generally outline the main laws protecting the quality of environmental waters, the quality of drinking water, and the safe reuse

[32] European Parliament, Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, 20/11/2014, https://eur-lex.europa.eu/eli/dir/2000/60/oj, Accessed 15/03/2024

[33] European Parliament, Directive (EU) 2020/2184 of the European Parliament and of the Council of 16 December 2020 on the quality of water intended for human consumption (recast), 23/12/2020, https://eur-lex.europa.eu/eli/dir/2020/2184/oj, Accessed 15/03/2024

[34] European Parliament, Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse, 5/6/2020, eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32020R0741&from=EN, Accessed 15/03/2024

of urban wastewater supplied to help address water scarcity. Throughout these EU regulations, there are several objectives that directly relate to the understanding of water consumption and requirements.

"The overall objective of EU water policy is to ensure access to good quality water in sufficient quantity for all Europeans." [35]

As such, understanding the water footprint of households within member states is pertinent to assess their capability to achieve these objectives, by understanding their current ability to meet demand for water, through public water supplies and indirectly through the production of goods and services. In addition, understanding whether improvements to water reuse infrastructure (drinking water and wastewater treatment facilities) are needed could help reduce the strain on freshwater resources and improve the circularity within EU water industries.

Adding quantitative targets to support this water footprint indicator would provide a benchmark for evaluating progress towards effective water management and conservation strategies. It is recommended that these targets are aimed at the reduction of national average water footprint (i.e: a specific percentage reduction), as well as encouraging the reuse of urban wastewater by setting a specific percentage target of the national average water footprint to be sourced from recycled water.

If this indicator was to be further developed and applied across the EU, it is recommended that the following points should be undertaken:

- Additional water consumption data at a household level across different countries should be collected and made available to use to improve the robustness and reliability of the indicator. The data gaps discussed in this report created challenges and limitations which made the data less accurate. For direct water consumption source data, this could be collected from water meters or water companies at a national scale. For more accurate results, it is recommended that the EC should incentivise the implementation of water meters across homes to allow for data collection on household water use. Data collection from water meters across all households would more accurately measure and record household usage. Supporting the facilitation of widespread water meter use and subsequently data collection will greatly influence the data availability and directness of the water indicator, due to the highly accurate household water use data recorded by the meters. While this implementation would also provide a further benefit of reducing water consumption through improved leakage control and network management, widespread rollout of smart meters in the UK alone has been estimated to cost billions of pounds[36]. Therefore, EU-wide support for smart meters may receive considerable push back from the water industry, and as such cost-benefit analysis for their implementation could be worth investing in prior to this.
- Food consumption data should be further improved to increase the robustness, reliability and replicability of the water footprint. Food data is highly valuable in determining water footprint as it accounts for over 95% of total household water use. Further data on water use per countries typical diet is required, such as through incorporation into existing national household surveys, to help estimate a typical household water footprint from food. The EC and other policymakers should support the collection of more granular data in this area by developing a data set on a typical diet per EU country to improve the accuracy and availability of such data. It is also recommended to account for all indirect imported water footprints from food, such as the water used in food products outside of the EU to ensure the data is covering scope of imported and exported food.
- Up to date data across all data sources discussed should be made available (post 2021) on Eurostat to gain more accurate temporal results, increasing the replicability of the indicator across years and countries. This will also improve the relevance of the indicator as more recent and therefore representative data is available to use. This could be implemented by the EC to develop and improve data availability on resources such as Eurostat.

[35] European Commission, Water scarcity and droughts – preventing and mitigating water scarcity and droughts in the EU, 2024, https://environment.ec.europa.eu/topics/water/water-scarcity-and-droughts_en, Accessed 15/03/2024

[36] Water Magazine, Gearing up for smart meter mass rollout: Q&A with Andrew Welsh, Water Utilities Director at Xylem UK, 2024, Gearing up for smart meter mass rollout: Q&A with Andrew Welsh, Water Utilities Director at Xylem UK - Water Magazine, Accessed: 22/07/2024

- Leakage rates should be taken into account when calculating a water footprint, as up to 40% of all abstracted water could be leaked before it reaches its destination of use (e.g. the household). As this water has been abstracted, it should be accounted for in the final water footprint value.

Following the testing process, the name “Water footprint of private consumption, at national level” was deemed to clearly convey the indicators function of measuring water usage by different EU nations households, and therefore is fit for purpose.

Table 3-12: Summary of recommendations for indicator H9

Type of recommendation	Recommendation	Timeline	Key stakeholders or partners	RACER Criteria addressed
Research and development of data: Grey and Black water	To include data regarding grey and black water into the calculations to factor in the proportion of water which is re-circulated into the processes of water use.	Short (0.5 – 1.5 years)	• **Responsible:** EC. • **Accountable:** EC. • **Consulted:** Water companies. • **Informed:** Water providers such as water treatment works (regional).	• **Robustness**
Legislation: Record household use data from water meters	The EC should incentivise (economic or commercial) the implementation of water meters across homes. This would allow for data collection on household water use from water meters, to more accurately represent usage.	Medium (1.5 – 5 years)	• **Responsible:** EC. • **Accountable:** EU Member States. • **Consulted:** Local Municipalities. • **Informed:** Water companies.	• **Robustness and Ease**
Research and development of data: Food	Support the collection of more granular data in typical diets by developing a data set on a typical diet per EU Member State. Develop data set on indirect imported water footprints from food, such as the water used in food products outside of the EU, to ensure the data is covering scope of imported and exported food.	Medium (1.5 – 5 years)	• **Responsible:** EC. • **Accountable:** EU Member States. • **Consulted:** Trade bodies. • **Informed:** Manufacturers.	• **Robustness and Credibility**
Research and development of current Eurostat data sets	Up to date data across all data sources discussed should be made available (post 2021) on Eurostat to gain more accurate temporal results.	Short (0.5 – 1.5 years)	• **Responsible:** EC. • **Accountable:** EC Eurostat. • **Consulted:** EC. • **Informed:** EC.	• **Robustness and Ease**
Research and development of data: Leakage rates of abstracted water	Leakage rates of abstracted water should be taken into account when calculating a water footprint. Leakage data should be collected from water companies and added to a centralised data set (e.g. Eurostat) for each EU country.	Medium (1.5 – 5 years)	• **Responsible:** EC. • **Accountable:** EU Member States. • **Consulted:** Water companies. • **Informed:** Water providers and Local Municipalities.	• **Robustness**

Type of recommendation	Recommendation	Timeline	Key stakeholders or partners	RACER Criteria addressed
	Where data is not available, it should be mandatory for all water providers to disclose and make available data on leakage rates. This could form legislation if required.			
Additional data sourcing of textile data	Current sources used for determination of textile goods prices were deemed inaccurate. It is recommended that more robust data sets should be utilised for this information in the future, such as nation-wide annual statistics of the consumer price index basket.	Short (0.5 – 1.5 years)	• **Responsible:** EC. • **Accountable:** EU Member States. • **Consulted:** EC. • **Informed:** EC.	• **Robustness**

4. APPENDIX

4.1 INDICATOR 1 – DATA

See MS Excel document “DGRTD H2 Household impact on biodiversity V01.00” provided alongside this report.

4.2 ALL INDICATORS - RACER ASSESSMENT 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.	

4.3 INDICATOR 2 – DATASET AND CALCULATIONS

See MS Excel document “DGRTD_H9_Dataset and Calculations_V01.00” provided alongside this report.

5. BIBLIOGRAPHY

Sandu, M. A., & Vîrsta, A. (2021). THE WATER FOOTPRINT IN CONTEXT OF CIRCULAR ECONOMY. *AgroLife Scientific Journal*, *10*(2), 170–177. https://doi.org/10.17930/AGL2021221

T: +44 (0) 1235 75 3000
E: enquiry-ee@ricardo.com
W: www.ricardo.com