CHEMICAL

BIODIVERSITY FOOTPRINT

Sectoral appendix

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A. PURPOSE OF THE DOCUMENT

The current **sectoral appendix** supports the **Chemical benchmark factsheet** and provides additional content that could not be included in the factsheet due to space constraints. Such additional content relates to the perimeter of the factsheet, more detailed results and charts and specific methodology and references.

In addition to the sectoral appendix, this factsheet is supplemented by two documents, common to all the factsheets:

- A **general appendix**, which provides methodological elements to understand how the sectoral benchmark factsheets are built and how computations and charts are obtained. It includes all the methodology and references which are common to all the factsheets, as well as guidance on how to read and use the factsheets.

- A **reading guide**, which explains the structure of the factsheets. It provides the main contents, definitions and necessary elements to know how to read the factsheets for readers with limited knowledge about the Global Biodiversity Score.

Figure 1 below encapsulates the four benchmark documents available for each sector.

Figure 1: The four benchmark documents.

B. WHAT DOES THE SECTOR INCLUDE?

The factsheet covers the chemical sector which is made of four EXIOBASE industries: “Chemicals nec” (82% of the chemical sector), “Plastics, basic” (14% of the chemical sector),, “P- and other fertiliser” (3% of the chemical sector) and “N-Fertiliser” (less than 1% of the chemical sector). After reflexion it was decided not to include the EXIOBASE sector “Manufacture of rubber and plastic products” and to assign it to a future benchmark factsheet covering the manufacturing industry. This decision was made based on the EXIOBASE classification that groups all four industries mentioned above in one industry group: “Manufacture of chemicals and chemical products” but keeps “Manufacturing of rubber and plastic products” in a separate industry group “Manufacture of rubber and plastic products”. The EXIOBASE industry “Chemical and fertilizer minerals, salt and other mining and quarrying products n.e.c” is not covered due to the lack of robustness of the mineral extraction impact factors (such as phosphorous extraction). Finally, the reason for including the NACE division basic pharmaceutical products and pharmaceutical preparations in the chemical factsheet is that it is covered by the EXIOBASE industry “chemicals nec”.

The figure below illustrates the correspondence between the EXIOBASE industry group and NACE divisions covered by the factsheet.

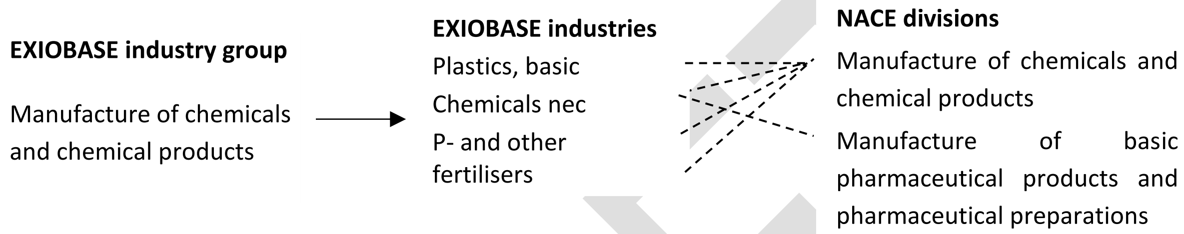


Figure 2: Correspondence between EXIOBASE industry groups and NACE divisions for the Chemical benchmark factsheet

These EXIOBASE industries correspond to divisions 20: Manufacture of chemicals and chemical products and 21: Manufacture of basic pharmaceutical products and pharmaceutical preparations of the NACE rev 2 classification.

The division 20 gathers all activities under “Manufacture of chemicals and chemical products”, namely:

- Manufacture of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms (20.3).

  Which excludes:
  - Extraction of methane, ethane, butane or propane
  - Manufacture of fuel gases such as ethane, butane or propane in a petroleum refinery
  - Manufacture of gaseous fuels from coal, waste etc.
  - Manufacture of prepared dyes and pigments (included in 20.3)
  - Manufacture of aromatic distilled water (included in 20.5)
  - Manufacture of crude glycerol (included in 20.4)
  - Manufacture of natural essential oils (included in 20.5)
  - Manufacture of basic metals
  - Manufacture of salicylic and O-acetylsalicylic acids (included in 21)
  - Mining of guano
  - Manufacture of agrochemical products, such as pesticides (20.2)
  - manufacture of artificial and synthetic fibres, filaments and yarn (included in 20.6)
  - Shredding of plastic products

- Manufacture of pesticides and other agrochemical products (20.3).
- Manufacture of paints, varnishes and similar coatings, printing ink and mastics (20.3).

  Which excludes:

  - Manufacture of fertilisers and nitrogen compounds (included in 20.1)
  - Manufacture of dyestuffs and pigments (included in 20.1)
  - Manufacture of writing and drawing ink (included in 20.5)

- Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations (20.4).

  Which excludes:

  - Manufacture of separate, chemically defined compounds (included in 20.1)
  - Manufacture of glycerol, synthesised from petroleum products (included in 20.1)
  - Extraction and refining of natural essential oils (included in 20.5)

- Manufacture of other chemical products, including the manufacture of explosives and pyrotechnic products, glues, essential oils and chemical products n.e.c. such as photographic chemical material or composite diagnostic preparations (20.5).

  Which excludes:

  - Manufacture of synthetic aromatic products (included in 20.1)
  - Manufacture of perfumes and toilet preparations (included in 20.4)
  - Manufacture of chemically defined products in bulk included in 20.1)
  - Manufacture of distilled water (included in 20.1)
  - Manufacture of other organic basic chemicals (included in 20.1)
  - Manufacture of printing ink (included in 20.3)
  - Manufacture of asphalt-based adhesives

- Manufacture of man-made fibres (20.6).

  Which excludes:

  - Spinning of synthetic or artificial fibres
  - Manufacture of yarns made of man-made staple

The division 21 gathers all activities under manufacture of basic pharmaceutical products and pharmaceutical preparations.

Which excludes:

- manufacture of herb infusions (mint, vervain, chamomile etc.)
- manufacture of dental fillings and dental cement
- manufacture of bone reconstruction cements
- manufacture of surgical drapes
- wholesale of pharmaceuticals

- retail sale of pharmaceuticals
- research and development for pharmaceuticals and biotech pharmaceuticals
- packaging of pharmaceuticals

Note that for all industries covered in the factsheet, downstream impacts are not taken into account within the computations and graphs included in the chemical factsheet. However, some of these downstream impacts may be accounted for in the computations and graphs of other factsheets. For instance, the downstream impacts of the P- and other fertiliser and N-fertiliser EXIOBASE industries are Scope 1 impacts for the agriculture sector.

C. ADDITIONAL DATA

1. Bio-based chemicals market

Bio-based chemicals are important to consider because of their high potential biodiversity impact. Biomass production contributes significantly to land use and pollution pressures and bio-based products are estimated to represent about 7.2% of the chemicals and chemical products industry (Piotrowski, Stephan, Carus, Michael, and Dr. Carrez, Dirk 2019) making the potential impact of the chemical bioeconomy significant.

The following figures (Figure 3 and Figure 4) show the European turnover of the bioeconomy and the production volumes of bio-based chemicals respectively.

When analysing results computed with the GBS™ it is important to consider bio-based products in the interpretation. The GBS uses EXIOBASE data from 2011 and the production volumes of bio-based products as well as the share of bio-based chemicals within the overall chemical industry were already significant before 2011. Furthermore, as can be seen on Figure 3 and Figure 4 if production volumes increased of about 3.5 million tonnes since 2011, the turnover of the bio-based chemicals and plastics industry remained approximately the same. Thus, it can be reasonably assumed that EXIOBASE data used in the GBS reflect the current bio-based market situation. You can find the results of a comparative impact study between bio-based and fossil-based ethanol in the additional results part (D.3.).

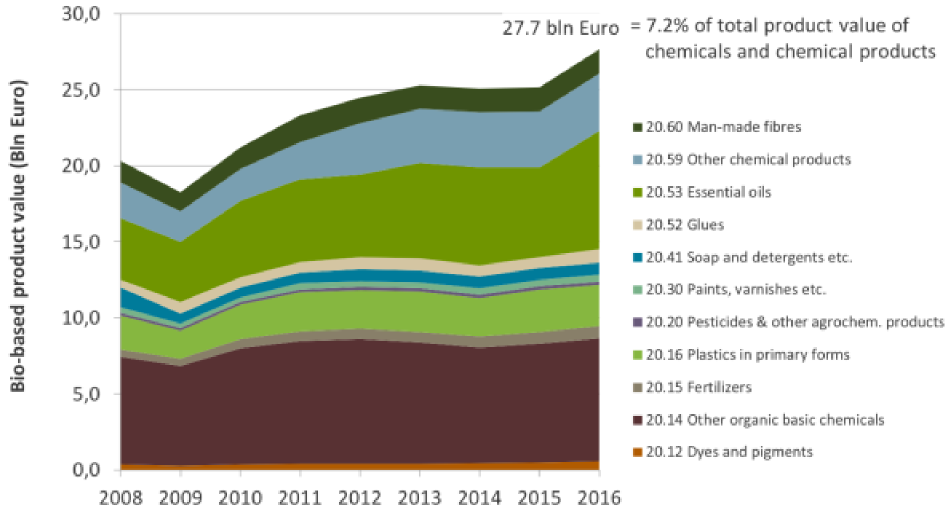


Figure 3: Contribution of NACE sub-industries to the total product value of bio-based chemicals in billion euros in the EU-28, 2008-2016. (Piotrowski, Stephan, Carus, Michael, and Dr. Carrez, Dirk 2019).

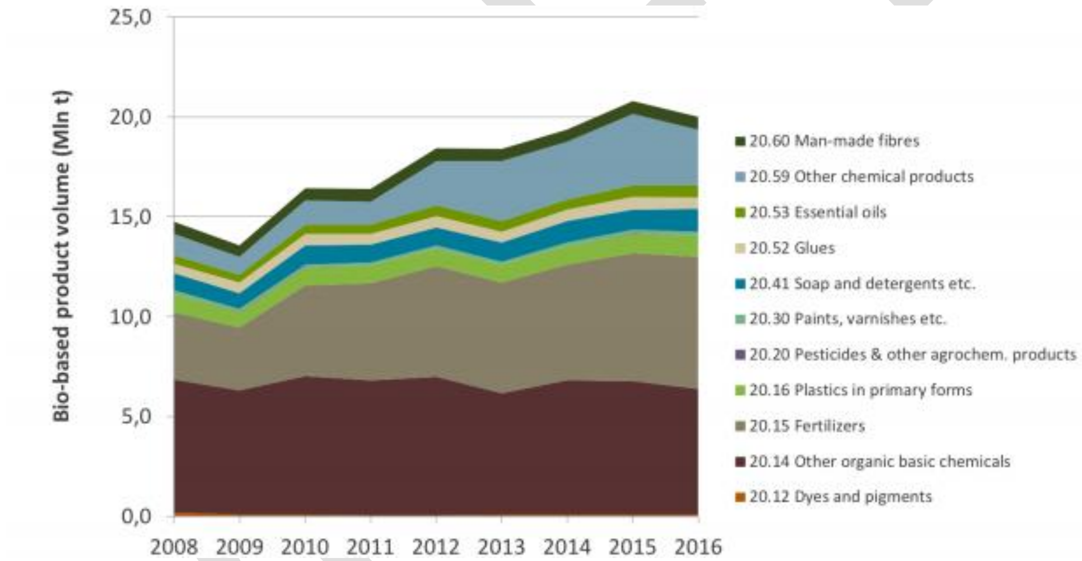


Figure 4: Contribution of NACE sub-industries to the total product volume of bio-based chemicals in million t, EU-28, 2008-2016. (Piotrowski, Stephan, Carus, Michael, and Dr. Carrez, Dirk 2019)

Values displayed in Figure 4 are volumes of finished goods. To better assess the biomass production, impacts tonnages of raw materials required to produce the goods must be made available.
In the European Union, the total biomass volume used in 2018 was 1 021 577 000t and the bio-based chemical sector used 0.1% of this domestic consumption, or about 1022 thousand tonnes. It also shows the highest growth rate of 48.4% between 2010 and 2015 (European Commission. Joint Research Centre. 2017)

Table 1 displays European production and consumption of ten bio-based chemical product categories representative of the European market for bio-based chemicals. The difference between production and consumption figures in solely due to imports and exports. There are significant variations in terms of production volumes and especially in the share of total production between product categories. Bio-based surfactants and cosmetics represent about 50% of their product categories production, while for platform chemicals and polymers for plastic, bio- based production only accounts for about 0.4%.

Table 1: Bio-based volumes and growth perspectives for 10 chemical product categories in the EU-28, 2018 (Spekreijse et al. 2019), consumption volumes are given in kilo tonnes per annum.

Product categories	Bio-based production	Bio-based consumption	Bio-based share in total production (%)	Expected annual growth (2018 -2025)
Platform chemicals[2]	181	197	0.3	10
Solvents	75	107	1.5	1
Polymers for plastics	268	247	0.4	4
Paints, coatings, inks & dyes	1 002	1 293	12.5	2
Surfactants	1500	1800	50	4
Cosmetics & personal care	558	558	44	3
Adhesives	237	320	9	10
Lubricants	237	220	3.5	1
Plasticizers	67	117	9	3
Man-made fibres	600	630	13	3

When considering all pressures on biodiversity bio-based products that are not produced from agricultural waste are likely to have higher impacts than equivalent petroleum products. However, in some cases bio-based products can provide environment-friendly solutions and lead to lower GHG emissions, but it is not always true as transformation processes may be responsible for significant GHG releases. For instance for packaging material, there is a bio-based resin that requires 65% less energy for production compared to fossil-fuel equivalents and a substitute to expanded polystyrene (EPS) made from potato residues and wood-fibers that produces 65% less CO_2 along its life cycle (van Crevel Rubie 2016).

2. Chemical release from the sector

The United States Environmental Protection Agency provides data on chemical released by industry according to the North American industry classification system (NAICS) code through its Toxic Release Inventory (TRI) programme. To represent the chemical sector defined by the factsheet only the NAICS sector chemicals (code 325) was selected. The factsheet does cover some sub-industry groups NAICS codes 312, 332 and 339 but it was considered more accurate not to include them in the selection for two reasons. First because only a minor portion

[2] A platform chemical is defined as a chemical that can serve as a substrate for the production of various other higher value-added products. (Takkellapati, Li, and Gonzalez 2018)

of the subsectors from these NAICS industry groups were covered by the factsheet and second because the Toxics Release Inventory (TRI) website does not provide a level of detail sufficient to select only the sub-industry groups covered by the factsheet. Out of the NAICS group 312, only 1 out of 9 subsectors is covered by the factsheet, of the group NAICS 332, only 3 out of 72 subsectors are covered by the factsheet, and of the group NAICS 339, only 3 out of 58 are covered by the factsheet.

The factsheet focuses on metal and metal compounds releases and only results for these chemicals are displayed. It was decided to focus on metals pollution in the factsheet due to their toxicity, persistence in the environment, and bio accumulative nature. However, the sector is also responsible for other chemical releases not displayed in the factsheet such as OSHA carcinogen, CERCLA hazardous substances, hazardous air substances or PBT chemicals. The following table displays the amount of the most significant chemicals released by the sector as given by the Environmental Protection Agency (EPA) during 2019. The following table displays the main metal and metal compounds emissions from the chemical sector per type, in tonnes for the year 2019[2].

Table 2: Metal and metal compounds releases in tonnes in 2019, EPA

Metal & metal compounds	Tonnes
Aluminum phosphide	42 168
Antimony & antimony compounds	22 898
Arsenic & arsenic compounds	7 548
Asbestos (friable)	2 857
Other metal & metal compounds	10 294

Table 3: Hazardous air pollutants releases in tonnes in 2019, EPA

Hazardous air pollutants	Tonnes
Methanol	17 134
Manganese compounds	16 907
Formaldehyde	7 094
Acetonitrile	6 257
Other hazardous air pollutants	54 424

Table 4: CERCLA chemicals releases in tonnes in 2019, EPA

CERCLA Chemicals	Tonnes
Ammonia	48 562
Nitrate compounds	32 710
Methanol	17 134
Manganese compounds	16 907
Other CERCLA chemicals	93 679

Table 5: PBT chemicals releases in tonnes in 2019, EPA

PBT Chemicals	Tonnes
Lead & lead compounds	766
Tetrabromobisphenol A	96
Polycyclic aromatic compounds	24
Mercury & mercury compounds	36
Other PBT chemicals	10

Table 6: OSHA chemicals releases in tonnes in 2019, EPA

OSHA chemicals	Tonnes
Formaldehyde	7 094
Acrylamide	2 751
Acrylonitrile	2 201
Styrene	1 451
Other OSHA chemicals	10 815

Table 7: Other material chemicals releases in tonnes in 2019, EPA

Other relevant chemicals	Tonnes
Ethylene	6 374
Zinc compounds	5 991
Formic acid	5 874
Carbonyl sulfide	4 128

3. N-fertiliser production process and emissions

Nitrogen-based fertilisers are manufactured by mixing nitrogen from the air and hydrogen from natural gas at high temperature and pressure so that ammonia is created. The ammonia is used to make nitric acid, with which it is then mixed to produce nitrate fertilisers such as ammonium nitrate (Fertilisers Europe 2019), the most used N-fertiliser in Europe. The energy consumed to produce it, mostly natural gas (Woods et al. 2010), the feedstock used to produce ammonia, N_2O emissions from nitric acid production and energy used to manufacture the fertiliser all contribute to GHG emissions. The feedstock is made from nitrogen and hydrogen which are combined using the Haber Bosch process which operates at high temperature and pressure leading the process to have high CO2 emissions, about 1% of global emissions, and high energy consumption, about 28 GJ per tonne of ammonia produced (Pattabathula and Richardson 2016).
Under the best available techniques defined by the EU and when using ammonium nitrate as a nitrogen compound, the overall manufacturing process emits 3.6 kg CO_2-eq per kg of nitrogen. Without best available techniques average emissions from European plants double (Yara 2020).

Greenhouse gas emission factors for Urea and Urea Ammonium Nitrate (UAN) production are between 1326 and 4019 g CO_2-eq per kg of N and between 1310 and 1844 g CO_2-eq per kg of N respectively.

Greenhouse gas emission factors for Ammonium Nitrate (AN) and Calcium Ammonium Nitrate production are between 2280 and 2461 g CO_2-eq per kg of N 1820 and 1983 g CO_2-eq per kg of N respectively (Wood and Cowie 2004).

D. ADDITIONAL RESULTS

1. Without ecotoxicity

The following calculations presented in the tables were made with the GBS 1.2.2 (October 2021 by Alexis Costes).

The figures and graphs do not include the Land-Use impact drivers in Scope 1 because no available data on land used by buildings was found. The Scope 1 impact is thus underestimated.

As mentioned in the factsheet a range for the impact of the sector (especially for the static terrestrial and the static aquatic impacts) has been defined because the impacts could not be determined with a higher accuracy. The graphs display the high boundary values of the range and figures may be overestimated. An analysis is being conducted to determine the footprint with more accuracy.

Table 8: Scope 1 impact intensities for the chemical benchmark, excluding ecotoxicity impacts, computation with GBS 1.2.2 in October 2021, by Alexis Costes

Accounting category	Realm	Footprint in MSA.m²/kEUR	Footprint in MSAppb/bEUR	Footprint in MSAppb/bEUR
Dynamic	Aquatic	0.00021	0.02	9.9
	Terrestrial	1.3	9.9	
Static	Aquatic	0.0082	0.8	2.8
	Terrestrial	0.26	2.0	

Table 9: Vertically integrated impact intensities for the chemical benchmark, excluding ecotoxicity impacts, computation with GBS 1.2.2 in October 2021, by Alexis Costes

Accounting category	Realm	Footprint in MSA.m²/kEUR	Footprint in MSAppb/bEUR	Footprint in MSAppb/bEUR
Dynamic	Aquatic	0.24	24	73
	Terrestrial	6.5	49	
Static	Aquatic	53	5100	9800
	Terrestrial	630	4700	

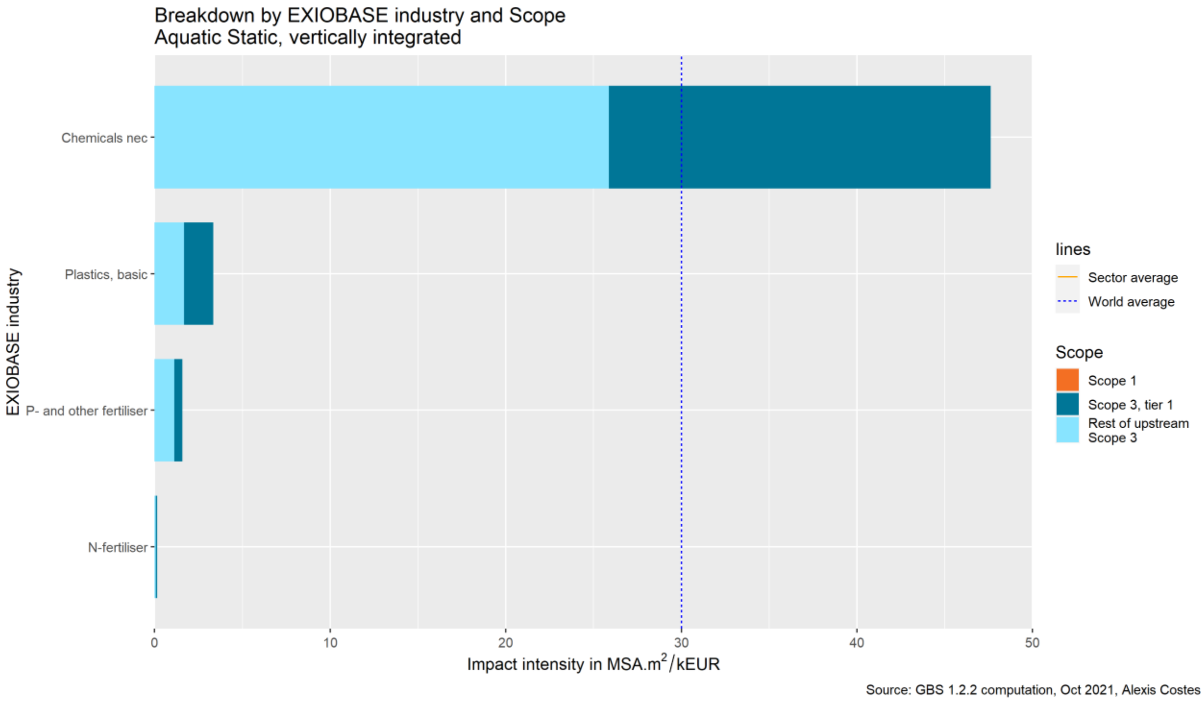


Figure 5: Breakdown by EXIOBASE industry and Scope, aquatic static, vertically integrated. MSA.m²/kEUR means MSA.m² per kEUR of turnover of the whole Chemical sector.

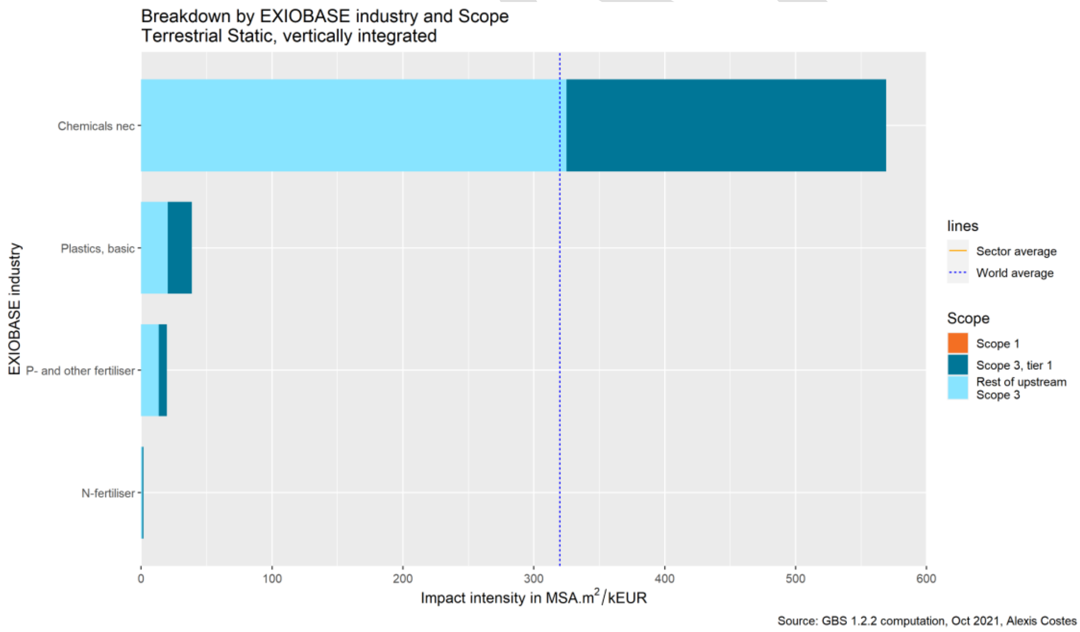


Figure 6: Breakdown by EXIOBASE industry and Scope, terrestrial static, vertically integrated. MSA.m²/kEUR means MSA.m² per kEUR of turnover of the whole Chemical sector.

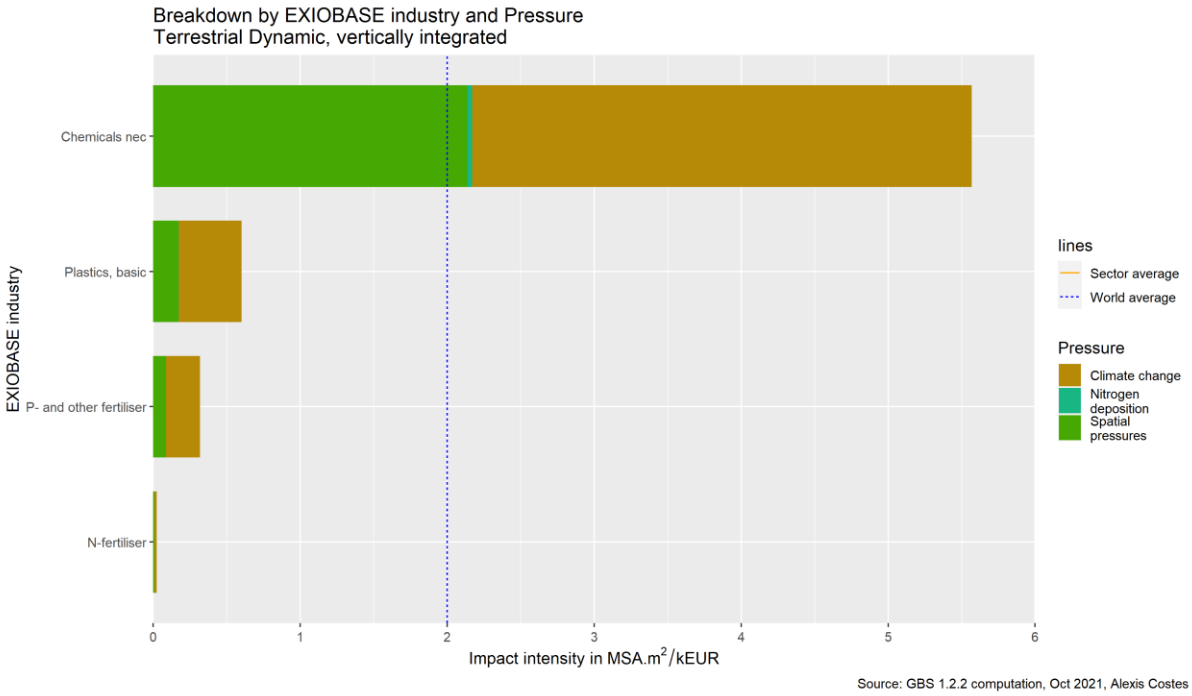


Figure 7: Breakdown by EXIOBASE industry and pressure, terrestrial dynamic, vertically integrated. MSA.m²/kEUR means MSA.m² per kEUR of turnover of the whole Chemical sector.

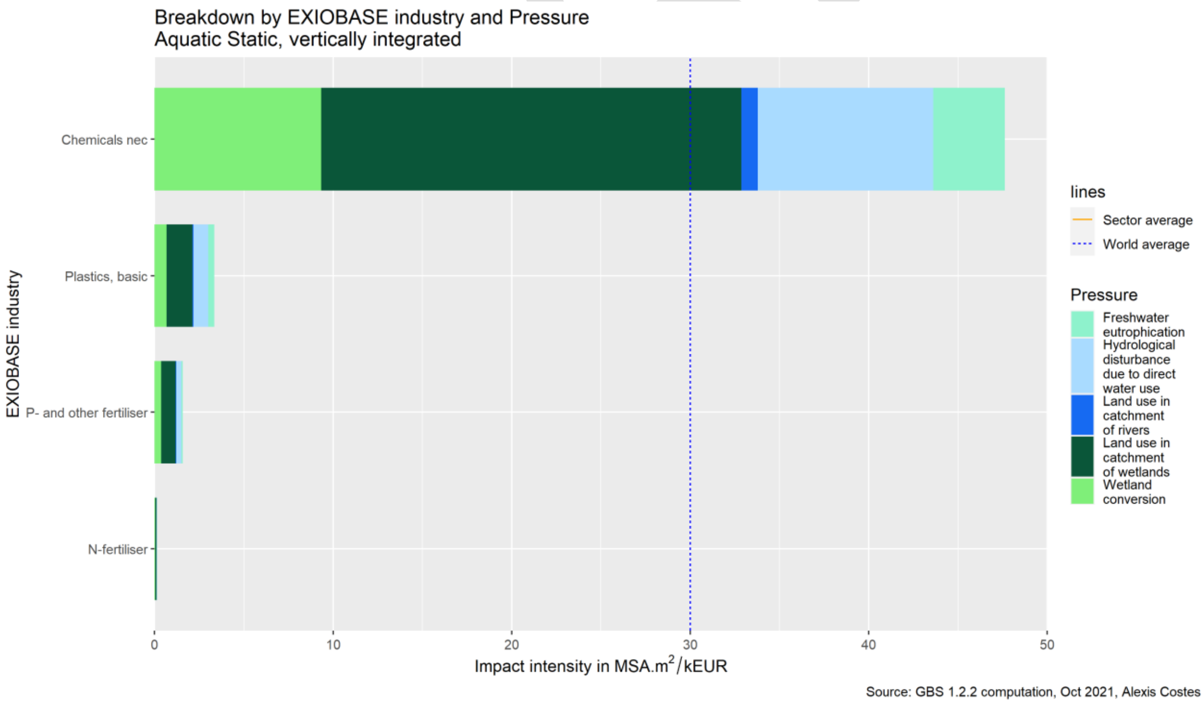


Figure 8: Breakdown by EXIOBASE industry and pressure, aquatic static, vertically integrated. MSA.m²/kEUR means MSA.m² per kEUR of turnover of the whole Chemical sector.

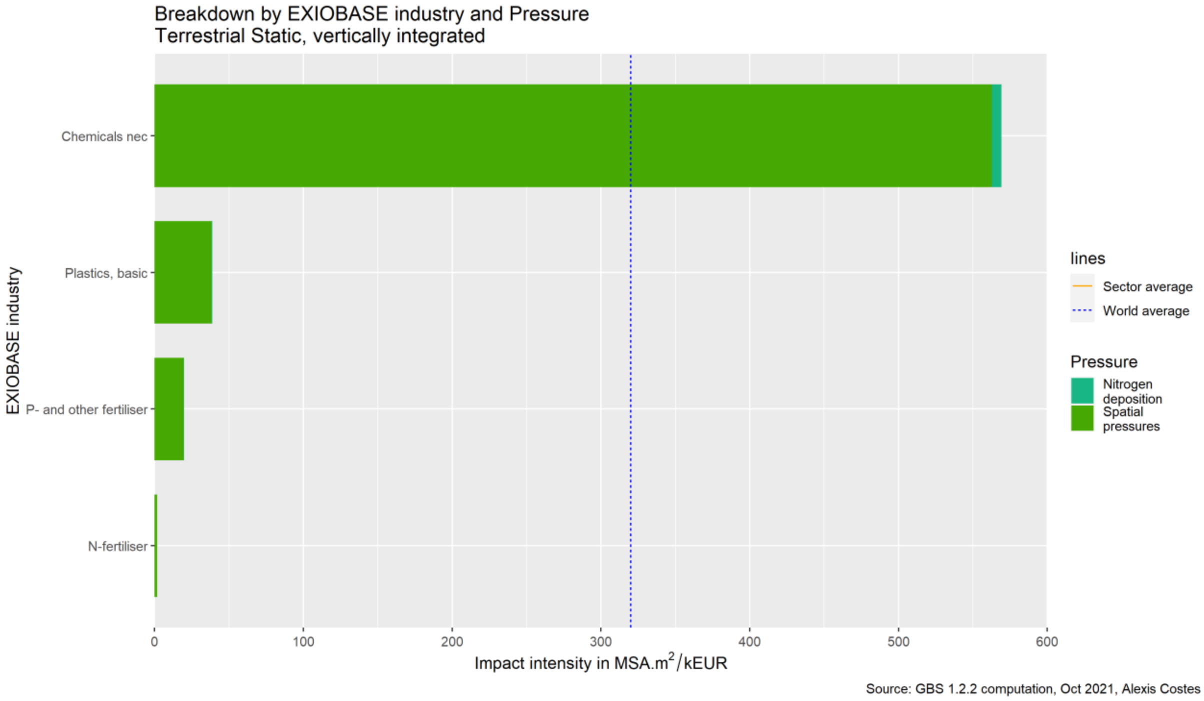


Figure 9: Breakdown by EXIOBASE industry and pressure, terrestrial static, vertically integrated. MSA.m²/kEUR means MSA.m² per kEUR of turnover of the whole Chemical sector.

Table 10: Breakdown for the most intensive EXIOBASE industries, per commodity type, terrestrial dynamic, vertically integrated (in MSA.m²/kEUR of the whole Chemical sector), computation with GBS 1.2.2 in October 2021, by Alexis Costes.

MSA.m²/kEUR	Crops	GHGs	Grazing	Oil and Gas	Wood logs	Metals, minerals and coal	Total
Chemicals nec	1.1	3.4	0.2	0.2	0.6	0.1	5.6
Plastics, basic	1,1	4,9	0,0	0,3	0,1	0,0	6,5

Table 11: Breakdown for the most intensive EXIOBASE industries, per commodity, aquatic static, vertically integrated (in MSA.m²/kEUR of the whole Chemical sector), computation with GBS 1.2.2 in October 2021, by Alexis Costes.

MSA.m²/kEUR	Crops	GHGs	Grazing	Oil and Gas	Wood logs	Metals, minerals and coal	Total
Chemicals nec	32	0	12	0.5	3	0.5	48
Plastics, basic	2.5	0	1	0	0	0	3.5

Table 12: Breakdown for the most intensive EXIOBASE industries, per commodity, terrestrial static, vertically integrated (in MSA.m²/kEUR of the whole Chemical sector), computation with GBS 1.2.2 in October 2021, by Alexis Costes.

MSA.m²/kEUR	Crops	GHGs	Grazing	Oil and Gas	Wood logs	Metals, minerals and coal	Total
Chemicals nec	335	0	145	10	75	10	575
Plastics, basic	35	0	10	0	0	0	45

A significant proportion of the static and dynamic impacts is caused by crops and grass commodities, which does not seem consistent. Among potential sources of error, one concerns possible inaccuracies in EXIOBASE purchases. In all cases, these impacts are not that material compared to other sectors (e.g. the crops and grass impact for the Cattle Farming sector within the industry group “Manufacture of food & beverage”).

2. With ecotoxicity

Ecotoxicity impacts computed with the GBS should be interpreted with caution, as considered ecotoxic substances are limited to metallic elements emissions from fossil fuels combustion.

Ecotoxicity impacts of the sector was computed with the GBS™, using EPA data on chemical substances releases in the United States in 2019 (see Paragraph C). It avoids to only consider financial data only, as it is a current limitation for ecotoxicity computations using the GBS™. The following graph shows the ecotoxicity impacts of chemical substances released in the environment by the chemical industry in MSA.km². The corresponding static aquatic and static terrestrial impacts linked to these releases are 500 MSA.km² and 120 MSA.km² respectively.

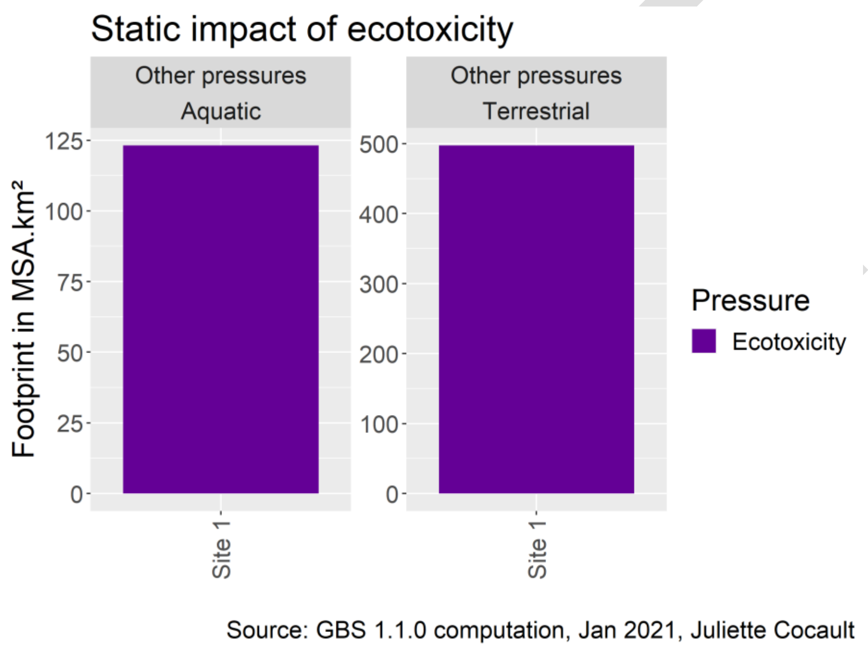


Figure 10: Static impact of the ecotoxicity pressure, aquatic and terrestrial, in MSA.km²

We used the great level of details provided by the US EPA to split emissions between air, water and soil emissions compartments in the most accurate manner, as can be seen in Table 13.

All substance releases to soil and water were classified under industrial soil and urban air respectively even in the case of “Off-site disposal” categories, as it was assumed that releases happened close to industrial sites and thus in areas that would still be classified as industrial soil and urban.

For most TRI disposal and release categories correspondences with GBS™ emissions compartments were evident: all injection wells, water discharges and wastewater treatment categories were classified as freshwater emission compartments, all landfill, land treatment, land disposal and impoundments categories as industrial soil compartments. Finally, all air categories were classified as urban and rural air compartments. Some categories were less straightforward and their classification as GBS emissions compartments rely on the United States Environmental Protection Agency (EPA) definitions[3] of the categories but are more arbitrary. It was decided to select the industrial soil emission compartments as the default choice. Thus, categories whose definitions did not provide enough information about the release media: POTW transfer- other releases, other off-site management, waste broker and unknown were assigned to industrial soil compartment.

Lastly for the remaining categories, storage only and solidification/stabilization, it was decided not to include them in the assessment as it is difficult to estimate if these chemicals will be released in the environment, in which medium and when.

For some TRI disposal and release categories, see Table 13, two GBS emission compartments correspondences were found and it was chosen to run various scenarios with different classification choices for relevant substances releases.

Table 13: Correspondence between TRI disposal and release categories and the GBS emissions compartments

TRI release media		GBS compartment	
		Option 1	Option 2
On-site Disposal to Class I	Underground Injection Class I Wells	Freshwater	
	RCRA Subtitle C Landfills	Industrial soil	
	Other On-Site Landfills	Industrial soil	
Other On-site Disposal or Other Releases	Fugitive Air Emissions	Urban air	Rural air
	Point Source Air Emissions	Urban air	Rural air
	Surface Water Discharges	Freshwater	
	Underground Injection Class II-V Wells	Freshwater	
	Land Treatment	Industrial soil	
	RCRA Subtitle C Surface Impoundments	Industrial soil	
	Other Surface Impoundments	Industrial soil	
	Other Land Disposal	Industrial soil	
Off-site Disposal to Class I Underground Injection	Underground Injection to Class I Wells	Freshwater	
	RCRA Subtitle C Landfills	Industrial soil	
	Other Landfills	Industrial soil	
	POTW Transfers - Releases to Class I UI Wells and Landfills	Industrial soil	Freshwater
Other Off-site Disposal or Other Releases	Storage Only	No release	
	Solidification/Stabilization (metals only)	No release	
	Wastewater Treatment-Metals Only	Freshwater	
	POTW Transfers - Other Releases	Freshwater	
	Underground Injection Class II-V Wells	Freshwater	
	RCRA Subtitle C Surface Impoundments	Industrial soil	
	Other Surface Impoundments	Industrial soil	
	Land Treatment	Industrial soil	
	Other Land Disposal	Industrial soil	
	Other Off-site Management	Industrial soil	
	Waste Broker	Industrial soil	
	Unknown	Industrial soil	

Some shortcomings of the GBS computation must be kept in mind when analyzing the results:

- 25 % of the overall volume of chemical releases reported by EPA were not taken into account by the GBS due to a lack of correspondence between ReCiPe substances and some CAS identification numbers.

[3] All categories definition can be found on the EPA TRI explorer website. After selecting the highest detail level for "report columns to include" and clicking on "generate report" it is possible to click on the heading of each column to see the definitions.

- Of the remaining 75%, 21% of the volume of chemicals released assigned to the urban air compartment (representing 4% of remaining releases volume) were not taken into account by the GBS for aquatic pressures.

The equivalent of the EPA TRI tool for Europe is the European pollutant release and transfer register tool from the European Environment Agency[4]. This tool has not yet been used but provides opportunities to better integrate chemicals released by different sectors and regions.

3. Comparison of the impact of bio-based and fossil-based ethanol

This comparative analysis of the biodiversity impact of a fossil based and a bio-based product aims at presenting the different pressures induced by bio-based and fossil-based chemicals and provide a starting point to reflect on the biodiversity impact of the chemicals sector shift to bio-based products, and whether this shift could be a solution for reducing biodiversity loss. This analysis only focuses on the production of ethanol and considers only six scenarios: fossil-based ethanol produced in Europe, wheat-based and sugar beet-based ethanol produced in France, sugar cane-based ethanol produced in Brazil (average between Centre-South and North-East region), maize grain-based and maize stover-based ethanol produced in the US.

To compare the biodiversity impact of a fossil based chemical and of its bio-based equivalent, the impacts of different production pathways of ethanol were evaluated, based on a comparative Life Cycle Assessment from (Muñoz et al. 2014). The midpoint indicators related to the production of 1kg of Ethanol under different scenarios were used as pressure data in the GBS to compute the related biodiversity impact.

The six scenarios assessed consider three indicators account: "Global warming potential (GWP)", "Agricultural land occupation (ALO)"," Freshwater eutrophication potential (FEP)". For wheat-based and sugar cane-based ethanol, land transformation data was available in the report from Muñoz (2.6.3). In the study, the crop expansion took place directly in forest without further details on the quality of the forest or the meadows, so we made a conservative assumption that natural areas were converted into natural forest, note that in the GBS, grasslands or natural forests both have a MSA of 100%.

The midpoint indicators show that bio-based ethanol production generates higher terrestrial static impacts than fossil-based ethanol. The GHG emissions generated by fossil-based ethanol are however two to three times more important as those generated by bio-based ethanol. Freshwater eutrophication potential is also superior for fossil-based ethanol than for bio-based ethanol.

Only three midpoint indicators were used out of six in the paper since other midpoint indicators are not covered by correspondent pressures in the GBS. Indeed, photochemical oxidant formation potential, terrestrial acidification potential and marine water eutrophication potential are indicators that do not correspond to pressure covered by the GBS and can thus not be entered as input data.

The following table shows the midpoint indicators mentioned above for the six scenarios, using fossil-based ethanol as the reference scenario: bio-based scenarios midpoint indicators are expressed relative to the fossil-based ethanol midpoint and endpoint indicators. This is to show the relative impact of ethanol production under

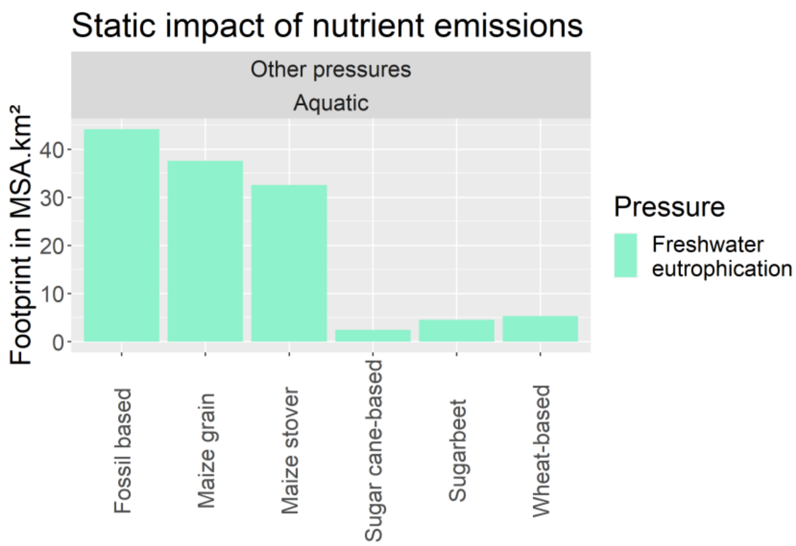
[4] https://prtr.eea.europa.eu/#/industrialactivity

the scenarios but does not illustrate the impact of a specific production volume. Endpoint indicators are those computed with the GBS using the midpoint indicators from Muñoz et al. research.

Table 14: Midpoint and endpoint indicators for sugarcane-based ethanol, wheat-based ethanol and fossil-based ethanol

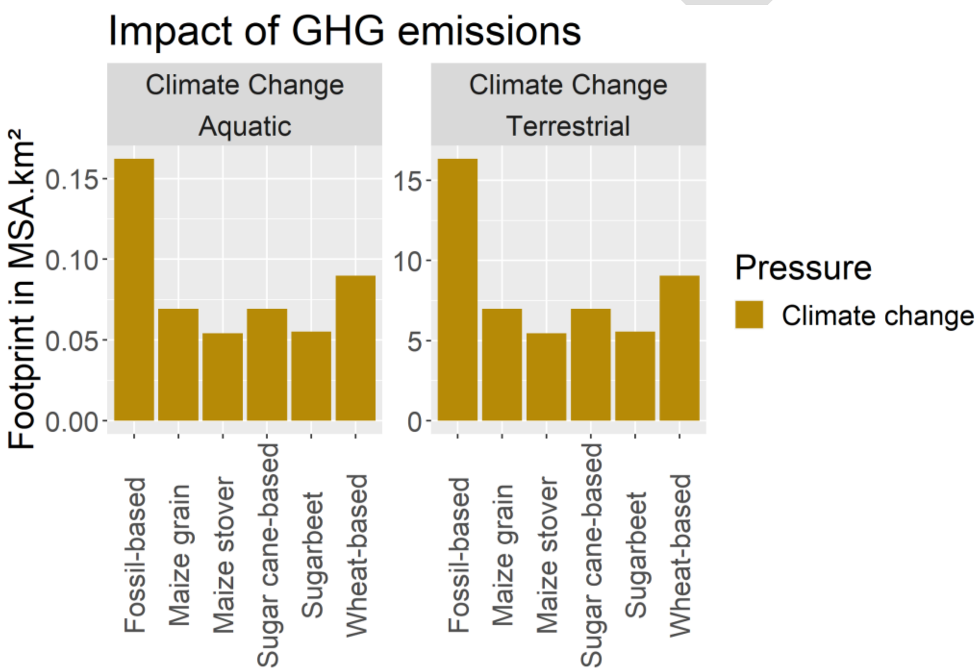
		Sugarcane-based ethanol	Wheat-based ethanol	Maize grain-based ethanol	Maize stover-based ethanol	Sugar beet-based ethanol	Fossil-based ethanol
Midpoint indicator	Global warming potential	0.43	0.55	0.43	0.33	0.34	1
Midpoint indicator	Freshwater eutrophication potential	0.28	0.45	0.96	0.83	0.38	1
Midpoint indicator	Land use occupation	251	278	123	93	87	1
Endpoint indicator	Climate change (dynamic)	0.44	0.56	0.44	0.34	0.34	1
Endpoint indicator	Hydrological disturbance due to climate change (dynamic)	0.43	0.56	0.43	0.34	0.34	1
Endpoint indicator	Freshwater eutrophication (static)	0.06	0.12	0.86	0.75	0.10	1
Endpoint indicator	Freshwater eutrophication (dynamic)	0.08	0	0	0	0	1
Endpoint indicator	Land use (static)	211	278	122	93	87	1

The following graphs show the biodiversity impacts resulting from the production of a million tonnes of ethanol under the six different scenarios and for the three main pressures. The impacts are computed with the GBS.



Source: GBS 1.2.0.0 computation, May 2021, Alexis Costes

Figure 11: Static freshwater eutrophication impacts for fossil-based ethanol and different bio-based ethanol



Source: GBS 1.2.0.0 computation, May 2021, Alexis Costes

Figure 12: Dynamic Climate change impacts for fossil-based ethanol and different bio-based ethanol

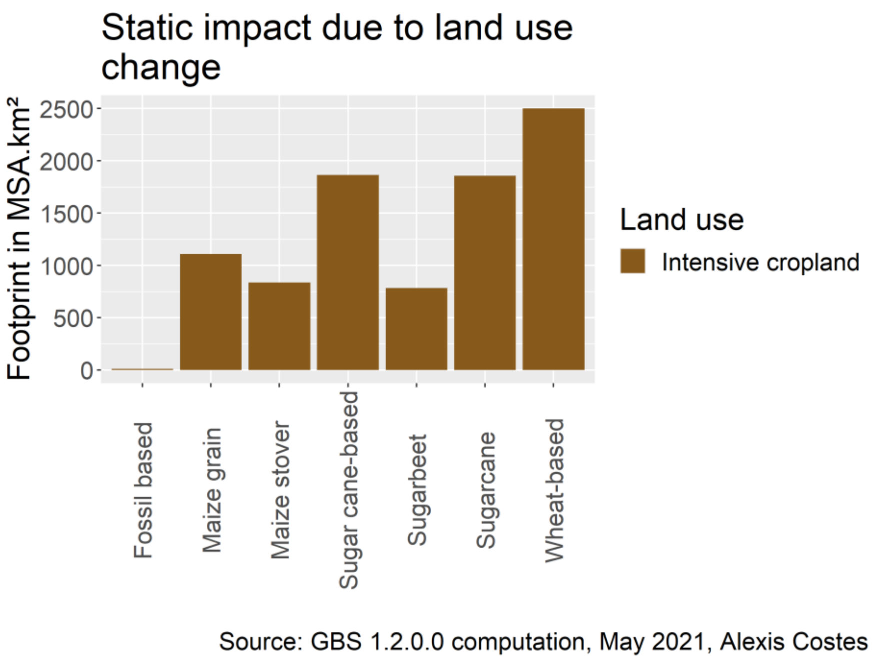


Figure 13: Static land use impacts for fossil-based ethanol and different bio-based ethanol

The graphs show that regarding terrestrial biodiversity, the best alternative is fossil-based ethanol while for aquatic biodiversity the best alternative is bio-based ethanol (note that maize-based ethanol freshwater eutrophication impact is close to the fossil-based one).

Table 15: Results of the comparative analysis between fossil-based and bio-based ethanol in MSA ppb

	Fossil-based ethanol	Maize grain-based ethanol	Sugar beet-based ethanol	Wheat-based ethanol	Sugar cane-based ethanol	Maize stover-based ethanol
Static	4100	12000	6400	20000	15000	9500
Dynamic	150	60	47	100	100	47

Results must be read with caution, only three midpoint indicators are considered in this analysis. For example, pesticide use is not included in the analysis, which could lead to underestimate bio-based ethanol impacts. Also, land use data from Muñoz et al. (2014) considers only the agricultural sector and not the extraction one, which means that impacts for fossil-based ethanol could also be underestimated.

This overall analysis has mixed results. Impacts are mainly due to land use pressures for bio-based ethanol, while fossil-based ethanol exerts greater pressures on Climate change and Freshwater eutrophication.

E. ADDITIONAL DNSH GUIDELINES

The main Do No Significant Harm criteria for the sector (EU Technical Expert Group on Sustainable Finance 2020a) are provided in the factsheets. Additional criteria which did not fit within the factsheet are listed below (EU Technical Expert Group on Sustainable Finance 2020b).

To not harm the objective of Circular economy and waste prevention and recycling, activities should:

Ensure that wastes and by-products, especially hazardous manufacturing wastes, are managed in line with the Waste Treatment Reference Document on Best Available Techniques (BREF) and the requirements set out in BREF LVIC- S

Ensure that wastes and by-products, especially hazardous wastes, are managed in line with the BREF for Waste Treatment. A minimum requirement is the implementation and adherence to a recognized environmental management system (ISO 14001, EMAS, or equivalent).

To prevent damage of vulnerable ecosystems activities should:

Ensure an Environmental Impact Assessment (EIA) has been completed in accordance with the EU Directives on Environmental Impact Assessment (2014/52/EU) and Strategic Environmental Assessment (2001/42/EC) (or other equivalent national provisions or international standards (e.g. IFC Performance Standard 1: Assessment and Management of Environmental and Social Risks) – whichever is stricter - in the case of sites/operations in non-EU countries) for the site/operation (including ancillary services, e.g. transport infrastructure and operations, waste disposal facilities, etc.) and any required mitigation measures for protecting biodiversity/eco-systems, particularly UNESCO World Heritage sites and Key Biodiversity Areas (KBAs), have been implemented.

For operations located in or near to biodiversity-sensitive areas, ensure that an appropriate assessment has been conducted in compliance with the provisions of the EU Biodiversity Strategy (COM (2011) 244), the Birds (2009/147/EC) and Habitats (92/43/EEC) Directives (or other equivalent national provisions or international standards– whichever is stricter - in case of sites/operations in non-EU countries) based on the conservation objectives of the protected area. For such sites/operations, ensure that:

- a site-level biodiversity management plan exists and is implemented in alignment with the IFC Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;
- all necessary mitigation measures are in place to reduce the impacts on species and habitats;
- a robust, appropriately designed and long-term biodiversity monitoring and evaluation programme exists and is implemented.

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Sources used in the Chemical benchmark factsheet are listed here.

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Contact:

Arthur Campredon
Director Footprint Measurement
arthur.campredon@cdc-biodiversite.fr

141, avenue de Clichy
75017 PARIS
T. +33 (0)1 80 40 15 00

contact@cdc-biodiversite.fr
www.cdc-biodiversite.fr

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RCS Paris 501 639 587
Siret 501 639 587 00028 - APE 6420Z
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